TrueNoord

TrueNoord Insight

Turboprop Market Report

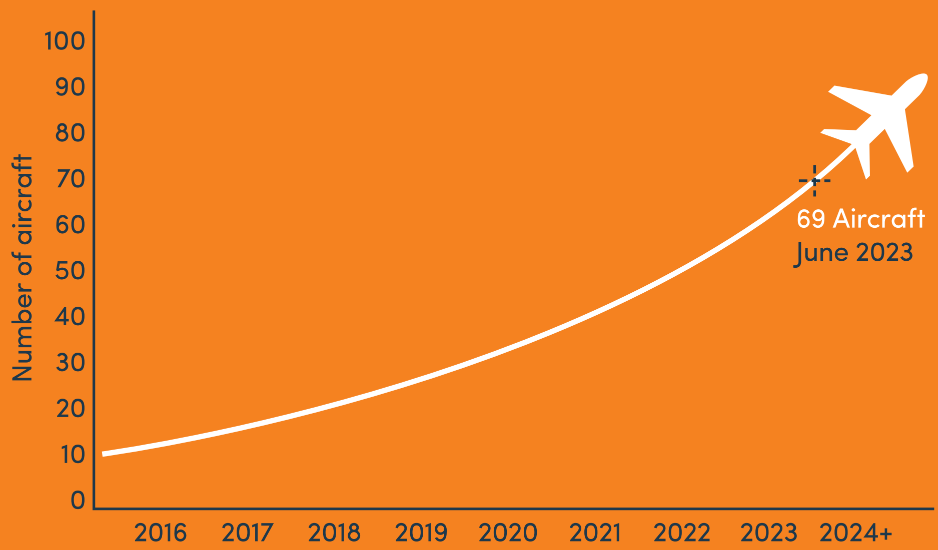
Exploring Future Technology

June 2023 | Angus von Schoenberg

Connecting people, communities and businesses across mature and developing economies worldwide

TrueNoord is a dynamic regional aircraft leasing company with offices in Amsterdam, Dublin, London, and Singapore. It is a full-service platform providing leasing and lease management services, supported by extensive knowledge of aircraft finance, to operators and investors worldwide in the regional sector.

Our trajectory



Contents

US-BANGLA AIRLINES

TrueNoord Fleet
3 ATR 72-600

Executive Summary

Current Turboprops

Strengths

- Best operating economics of any sub 150 seat aircraft on sectors up to 300nm.
- Optimised for performance driven missions e.g. short runways.
- Increasingly well diversified global operator base.
- Much improved acceptance of this asset class among lessors and finance community.
- Long economic useful life.
- Best environmental footprint of any aircraft class for short sectors not only due to attractively low carbon emissions but, unlike jet aircraft, turboprops do not generate contrails.

Weaknesses

- Perceived lower on-board product quality and reduced on-board baggage capacity.
- Lower appeal to network carriers compared to regional jets for hub and spoke operations particularly in US market.
- Limited range capability.
- Lack of significant technological advancement in this century particularly in relation to power plant.
- Little scope to stretch existing airframes to meet demand for larger aircraft.

Opportunities

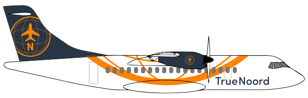
- Significantly underserved markets ideal for turboprops remain in Asia, Latin America and Africa.
- Any continued fuel price increases or new taxes on aviation fuel imposed at national or supra-national level will increase the attractiveness of turboprops relative to other types.
- Represent the main candidate airframes for hydrogen propulsion system retrofit.

Threats

- Future hybrid and electric powered aircraft will impact existing turboprop fleets before any other types.
- Continued technological and economic improvement of regional jet aircraft could erode benefits of large turboprops.
- Introduction of a new 90-100 seat turboprop could reduce the appeal of current generation 70-90 seaters.

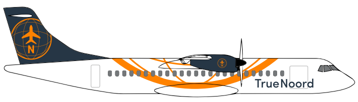
Key Attributes & Market Position of ATR and Dash 8-400 Turboprops

ATR42



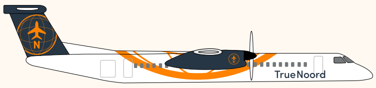
- Originally a 42 seater, but for many years the standard capacity has been 48 seats.
- Currently the only in-production 40-50 seat turboprop. Deutsche Aircraft D328Eco, despite its smaller capacity, could become a competitor over the coming years.
- Newest variant the ATR42-600S will give it a short take-off and landing capability on 800m runways with reduced payload of 40 passengers.
- Well established and geographically spread network of support and training facilities.
- Given total fleet of some 170 aircraft, the type has a remarkably broad operator base of around 60 carriers across all -500 and -600 variants. Six ATR42-600 operators so far.
- Only one ATR42 operator has more than 10 aircraft.
- Reasonable order book of 30 units relative to its total market size.
- Relatively few (6) newer generation ATR42-600s currently inactive.
- Average fleet age of ATR42-600 is about 5 years whereas the average age for the total ATR42 fleet is considerably greater.
- Some 30% of all ATR42s are leased. NAC with 28 aircraft is its largest lessor.

ATR72



- Standard capacity varies between 68 and 72 seats, but more seating enabled by new generation slim seats allows for a 78 seat high capacity version, which operates exclusively in Asia.
- Currently the only in-production large turboprop.
- Well established and geographically spread network of support and training facilities.
- The most successful large turboprop programme in history as measured by size of fleet and outstanding orders. Over 1,200 aircraft built of which, the latest ATR72-600 in service since 2011, has over 600 units in operation or on firm order (139 orders as at Dec 2022). Historically most other turboprop programmes never sold more than 350 units.
- The operator base is well diversified with in excess of 80 ATR72-600 operators alone particularly in the APAC region. There are six operators with more than 20 aircraft representing some 25% of the global fleet.
- Asia and Europe are the two largest markets for the type.
- The ATR72 is well established in the leasing community with 58% of ATR72-600s owned by lessors and 38% of ATR72-500s. NAC and Falko are currently the largest lessors of the type.
- Although many aircraft are recorded as stored, there are few airworthy examples available on the used market. The remainder require substantial maintenance related investment.
- Newest version is the ATR72-600 are powered by Pratt & Whitney Canada PW127XT engine, first delivered to Air Corsica in Dec 2022. The new engine offers longer maintenance intervals and an incremental fuel-burn improvement of up to 3%
- Next generation ATR72-600EVO are under development and will have incremental evolutionary efficiency improvements that may include the so called "mild-hybridisation" of engines.

Dash 8-400



- Standard capacity ranges from 78-82 seats. Some early examples have 74 seats. Extra capacity variants of 86 or 90 seats exist enabled by slim seats in the Asian market.
- Launched in 2008, the NextGen (NG) version featured an upgraded interior including larger overhead bins and an increased design weight.
- The aircraft is currently out of production following the closure of its Final Assembly Line (FAL) in Downsview. De Havilland have plans to develop a new FAL in Calgary, but this depends on future demand.
- The aircraft offers stronger performance characteristics than the ATR72 with greater speed (if required), climb performance and range, due principally to its larger more powerful engine. Consequently, the aircraft is often favoured over the ATR in mountainous or hot and high regions including Africa. However, the aircraft has higher operating costs per seat than the ATR72 particularly in relation to maintenance of the PW150A engine, which has a shaft horsepower output of over double that of the PW127.
- This aircraft has been the most successful Dash 8 programme to date with around 575 aircraft delivered.
- The operator base is reasonably diversified with 60 operators. However, the fleet is more concentrated. The ten largest operators with more than 20 aircraft account for nearly half the fleet.
- Geographical fleet dispersion is good in North America and Africa and reasonable in Asia. Its European footprint is declining.
- The aircraft is established in the leasing community with 40% of all Dash 8-400s owned by lessors. NAC, Falko and Aergo are the largest lessors of the type.
- There are more used aircraft available than ATRs. However, a substantial proportion require substantial maintenance related investment and it is likely that some, particularly older examples, may not go back into service.

Future Technology Aircraft Prospects

- New technology aircraft with either hydrogen or electric or hybrid propulsion systems are under increasingly advanced stages of development.
- Such aircraft will first enter service in the 9-30 seat regional commuter category in the hybrid electric segment.
- Hydrogen powered aircraft may first become available on ATR72 sized aircraft, but are likely to have reduced payload and/or seating capacity.
- Other than a 9-seater Eviation Alice, a Zeroavia powered 19 seat Dornier 228 and a Universal Hydrogen powered 40 seat Dash 8-300, no regional aircraft prototypes have yet flown and initial test flights were only for about 10 minutes.
- Some of the new technology aircraft OEMs are projecting entry to service dates from as early as late 2025.
- However, the final design specification for any of the aircraft has yet to be frozen.
- Once the final design of any new aircraft is settled and prototypes are constructed, the main certification process can begin. Certification of any new aircraft, even when based on proven conventional technology usually takes several years.
- The new technology aircraft OEMs are all start-up companies without a developed support infrastructure comparable to established aircraft manufacturers.
- In order for new technology aircraft to be successful the necessary hydrogen and or power supply needs to be available at enough airports.

Current Generation Turboprop Values and Lease Rates

Values

- New ATR72-600 values are in the region of US$21 million.
- The newest Dash 8-400 values of aircraft manufactured in 2021 are in the range of US$19.5 million.
- Values for used ATR72-600 began to recover during 2022 as the supply of airworthy good condition aircraft began to diminish considerably.
- Values for used Dash 8-400s remain weak although these have also begun to recover mainly for newer NG vintages.
- Due to its more concentrated operator profile the Dash 8-400 has suffered more from airline bankruptcies and the decision of some carriers in Europe and North America to dispose of their fleets to a greater extent than the ATR.
- Older 1990s ATR72-500 vintage values have stabilised to serve the cargo conversion market.
- The long-term impact of the sale of the Dash-8 programme by Bombardier on values remains uncertain. Concerns remain with respect to the future of the programme and also with the support of the incumbent fleet by De Havilland and P&WC. However, the Dash 8 is well regarded by loyal operators as a robust aircraft and previous Dash 8-100/200/300 models remained in strong demand after production had ceased.

Lease Rates

- New ATR72-600 lease rates are in the range of US$170,000 per month. Although naked, almost-new aircraft, from past forward orders have been recently offered at lower rates.
- Like values, lease rates for used ATR72-600s have begun to increase and this is now confirmed by all appraisers.
- New ATR42-600 values are in the region of US$130,000.
- Lease rates for the Dash 8-400 have also begun to recover in the region of US$160,000 for recent 2021 examples, down to US$70,000 for 2010 vintage examples.
- Insufficient cost and pricing data is available to indicate the values and lease rates for any of the new generation aircraft that we believe will not come to market at any scale before 2030.

TrueNoord Fleet
3 Dash 8-400

1 Introduction & Scope

Aircraft Types covered in this Report

ATR72-600

The French-Italian ATR72 was first launched in the late 1980s as the ATR72-200. The -200 series was superseded by the -500 series in 1995, which, in turn, was further developed into the latest -600 series variant from 2011. Initially the ATR72 was a 68-72 seat aircraft. The standard European versions are now 70-72 seats, but today a high density 78 seat version is also available and operates exclusively in Asia.

The ATR72 is the world's most popular current generation turboprop and is considered to be the work horse of a majority of regional airlines outside North America where the regional market is dominated by jet powered aircraft. The ATR72-600 has become the dominant regional aircraft in Asia over the past decade.

ATR42-600

While the first prototype aircraft was the ATR42-200, very few 200 variants entered commercial service and the standard initial version became the ATR42-300. The first in service aircraft pre-dated the ATR72 with service entry in 1985. Prior to the current ATR42-600 the platform had more intervening variants than its larger sibling comprising -320, -400 and -500 versions each of which embodied certain upgrades. The ATR42-600 has 48 seats in its standard configuration. Its next forthcoming iteration is the ATR42-600S to enable Short Take-Off and Landing (STOL) capability.

Dash 8-400

This aircraft (previously branded by Bombardier as the DHC8Q-400 or simply the Q400) is the world's largest turboprop commercial airliner. First entry to service was in 1998 with SAS when the standard configuration was 74 seats. Today the densest version has increased to 90 seats with SpiceJet in India, but more commonly the aircraft has 78-82 seats.

The aircraft was developed in the 1990s as a high-speed turboprop (360 knots high speed cruise compared to 270 knots high speed cruise for the ATR72) in order to compete with regional jets on shorter sectors but with the aim of achieving turboprop economics particularly in relation to fuel burn. At the time, Bombardier believed such an aircraft would perfectly complement its CRJ regional jet range, which was optimised for thin markets on longer sectors in excess of ninety minutes. While the Dash 8-400 has not seen the same commercial success as the ATR72, it has nevertheless sold in excess of 500 aircraft, a similar volume to its discontinued smaller and earlier Q100/200/300 family. The Dash 8 programme is now owned by De Havilland after the completion of its sale by Bombardier earlier in 2019. Production of the aircraft ceased in mid-2021 due to a lack of orders and a need to vacate its assembly line in Downsview, Toronto, following the sale of the site to developers. In July 2022 De Havilland announced that it is exploring a new production facility in Calgary to re-start production subject to demand and a sufficiently robust supply chain.

Future Technology Aircraft

There is a multitude of new technology aircraft projects many of which are still at a research and development stage with no projected service entry timetables. This report cannot cover all such projects and will therefore primarily focus on those where a commercial service entry year has been announced. This includes:

- Future variants of current generation aircraft including the ATR72EVO, which plans to adopt mild hybridisation to enable an electric power boost for take-off and climb.
- Pure and hybrid electric powered aircraft ranging from the 9-seat Eviation Alice, the 19 seat Aura ERA, the 30-seat Heart Aerospace ES30 to Maeve Aerospace's all electric 44-seat Maeve 01. The all-electric Alice completed its first test flight in September 2022, and the ES30 plan has evolved from a pure electric 19 seat aircraft to a larger hybrid platform.
- Hydrogen powered retrofit programmes for current generation turboprop aircraft including those of ZeroAvia and Universal Hydrogen. Both of these are currently undergoing trials on the Dornier 228 and Dash 8-300 prior to testing on larger airframes such as the ATR72.

Scope

The previous Large Turboprop Report (June 2020) provided an overview of the 70-90 seat turboprop market primarily covering the above referenced ATR72 and Dash 8-400. This revised and updated report will continue to primarily focus on the ATR72-600 and Dash 8-400. TrueNoord already owns 21 ATR72-600s and since the previous report has also acquired five Dash 8-400s. Over the last year, TrueNoord has also added 4 of the smaller ATR42-600 aircraft so this report's scope will broaden to cover the lower number of seats in this aircraft.

Furthermore, as all the new technology aircraft platforms involve lower seating capacities this report will also address future generation turboprops from 19-90 seats with only cursory references to the smaller capacity aircraft such as the Alice. (Short range urban air mobility projects often referred to as eVTOLs are excluded). 19 seats as a lower boundary has been selected as this has historically been considered a size at which at least some airlines would adopt such aircraft for commuter or small regional operations. It is also the size above which a cabin attendant is required. While not covering the existing generation of turboprops below 50 seats, which have been out of production since before this century, some references are required in addressing the new technology platforms.

For the in-service aircraft types, this report will examine aircraft characteristics, applications, market penetration, and operating economics, as well as addressing the current dynamics in values of these aircraft which continue to see some variety of values from the appraisal community.

With respect to future technology, the report will examine characteristics to the extent that these are known, the possible timelines for entry to service, technical, and certification challenges remaining. Any initial operating cost data available will be examined along with a review of the commitments placed so far by potential operators.

Embraer's Energia H2 Gas Turbine E50-H2GT

2 Summary Specifications, Performance, Economics and Developments

2.1 Development Timeline

Current Generation Aircraft

The ATR comprises a current generation two aircraft family: the ATR42-600 and the ATR72-600. The programme was launched in 1984 as the 42 seat capacity ATR42-300 and followed in 1988 by its larger 68 seat capacity ATR72-200 sibling. These aircraft were powered by Pratt & Whitney Canada PW120/121 and 124 series engines with four bladed propellers.

From 1996 onwards the family was substantially upgraded with the current generation of PW127 engines with six bladed propellers and marketed as the ATR42/72-500. The ATR72 was also offered with increased capacity of 72 or 74 seats. Other developments at the time included improved performance and a higher maximum take-off weight. During this period other turboprop manufacturers, including Saab and Fokker, ceased production and Bombardier launched a stretch of the DHC8-300, which became the DHC8Q-400 (now branded the Dash 8-400) and is the only competitor to ATR. The timeline of both the Dash-8 and the ATR variants are shown in Figure 2.1.

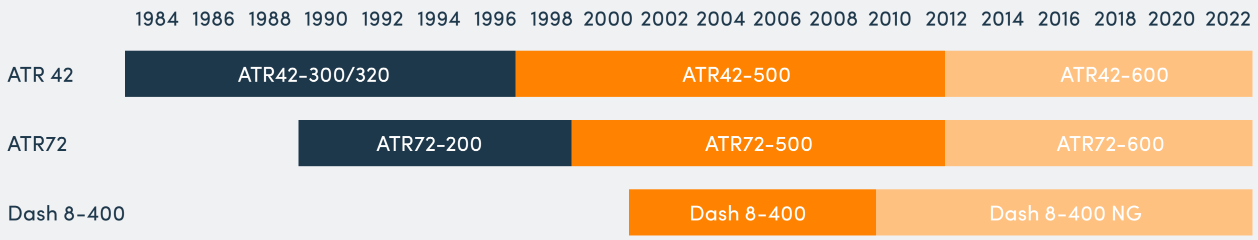
In 2008 ATR launched the current -600 generation, which first went into service in 2011. For a period of some 12 months both the -500 and -600 were produced in parallel for those customers seeking to maintain a consistent -500 fleet.

By contrast, the Dash 8-400 is a substantial redevelopment rather than just a stretch of the previous Dash 8-100/200/300 family of 37-50 seat turboprops. To accommodate the larger capacity of the aircraft, the previous aircraft was not only stretched by 6.8m compared to the Dash 8-300, but has a larger wing, is constructed with newer generation lighter materials, but most importantly is powered by the PW150A engine that was designed for this aircraft and any future stretched versions.

Both ATR and Bombardier have considered larger 90-100 seat turboprops. However, Bombardier (previous owner of the Dash 8 programme), whose resources were focused on the former C-Series (now the A220), concluded that a further stretch of the aircraft posed significant design risks and shelved the Q400X programme. Subsequently ATR's Italian shareholder continued to push for a larger aircraft, but Airbus as the other main shareholder was against a new turboprop so that this project was also abandoned less than a year later than the Q400X.

Earlier in 2022, De Havilland officially paused production of the Dash 8-400 because the final assembly line site in Downsview had been sold. Depending on future demand, production may recommence in Calgary. This means that ATR remains as a near monopoly supplier of 48-78 seat turboprops for the near-term future, although Embraer has been considering a 90 seat aircraft.

Figure 2.1: ATR42/72 and Dash8-400 Production Timeline



Source: TrueNoord Insight

Future Technology Aircraft

For a number of reasons that will be addressed in subsequent sections of this report the timetable for Entry Into Service (EIS) for new technology is uncertain, but the manufacturers of advanced projects in the commuter and regional segment are currently projecting EIS in the second half of the decade. Figure 2.2 shows those projects which have publicly announced an EIS date. There are also other concept aircraft including Embraer's 19 and 30 seat hybrid Energia for an estimated EIS in the early 2030s, but this is not yet a committed development programme and is therefore considered out of scope for this report. Maeve Aerospace has also launched a concept for an all-electric 44-60 seat regional aircraft and currently projects service entry in 2029.

Figure 2.2: Current Projected New Technology Aircraft EIS

	<20 seats	>40 seats	Propulsion System
Universal Hydrogen	NA	2025	Hydrogen fuel cell
ZeroAvia	2025	2026	Hydrogen fuel cell
Aura ERA	2027	NA	Hybrid electric & turbogenerator
Heart ES30	NA	2028	Hybrid electric & turbogenerator
Maeve 01	NA	2029	All electric
Eviation Alice	2026	NA	All electric
ATR72EVO	NA	2030	Mild Hybridisation

2.2 Specifications

2.2.1 Configuration and access

Following the trend by all manufacturers to increase seating capacity, both ATR and De Havilland offer high-capacity configurations enabled by the development of slim passenger seats. Their high-capacity variants are shown in Figure 2.3 with 78 seats for the ATR and 90 for the Dash 8. These versions are primarily aimed at the high growth Asian continent where the average weight per passenger with baggage is lower than Europe or North America.

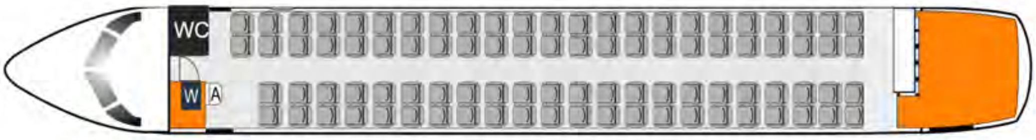
In other parts of the world, the standard configuration remains at 70/72 seats for the ATR and 78/82 for the Dash 8 (Figure 2.4) the latter of which also has 74 and 76 seat versions.

The ATR42-600 as shown in Figure 2.5 has a standard capacity of 48 seats. From late 2022 ATR also offers a 30-seat configuration with additional cargo capacity or a 34" pitch variant. As this version matches its recent certification in China for a maximum of 30 seats, this aircraft can be aimed at that market.

Figure 2.3: ATR72-600 and Dash 8-400 High-Capacity Configurations

ATR72-600 78 seats SINGLE CLASS @ 28”

Dash 8-400 90 seats SINGLE CLASS @ 28”

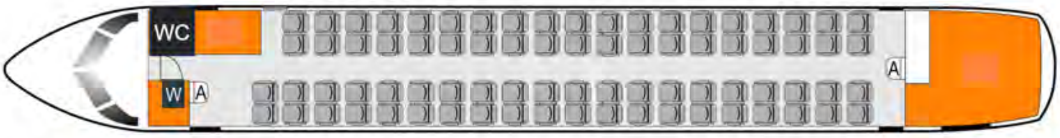


Source: TrueNoord Intelligence, ATR & De Havilland

Figure 2.4: ATR72-600 and Dash 8-400 Standard Configurations

ATR72-600 72 seats SINGLE CLASS @ 29”

Dash 8-400 78 seats SINGLE CLASS @ 29”

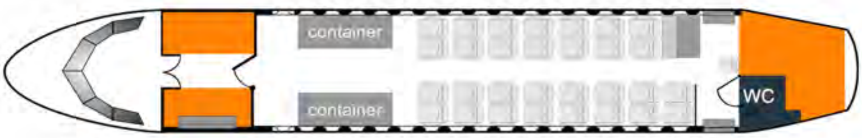


Source: TrueNoord Intelligence & ATR

Figure 2.5: ATR42-600 Configurations

ATR42-600 48 seats SINGLE CLASS @ 30”

ATR42-600 30 seats SINGLE CLASS + 700kg additional cargo



Source: TrueNoord Intelligence, ATR & Jambojet

Access

From an aircraft servicing perspective, the passenger door is located at the rear of the ATR while the Dash 8 has conventional front access. This means that airbridges cannot be attached for rear boarding to the ATR. While airbridge access is not used for turboprops in most of the world, North America is the exception. This, in combination with its higher 25,000ft operating ceiling and greater on-board luggage capacity, is a major reason why the Dash 8 has traditionally been favoured over the ATR in that market. Furthermore, since most US carriers offer first class seating even in their regional aircraft operations and these seats are at the front of the aircraft, rear boarding presents logistical complexity.

Future Technology Aircraft

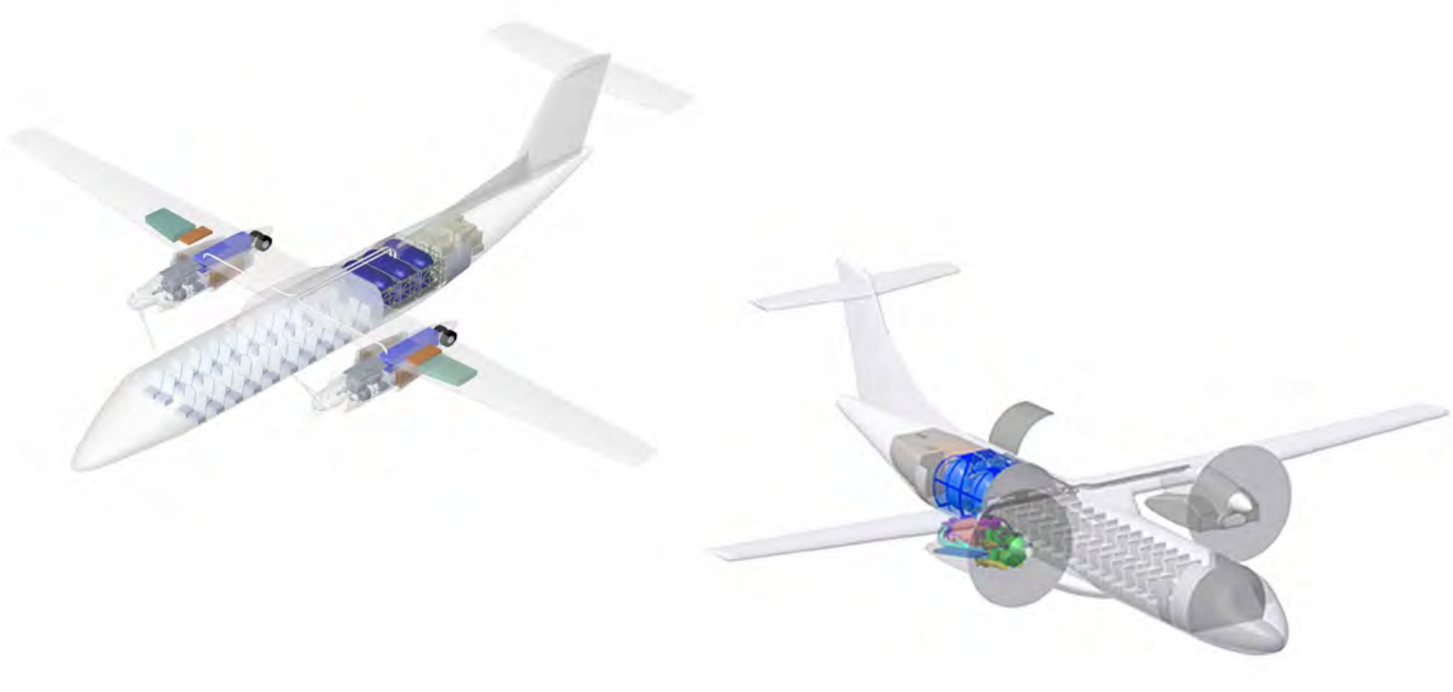
As yet there are no publicly available seating lay-outs for these aircraft. However, a schematic of the hybrid electric ES30 shown in Figure 2.6 is available. This recently revised design is to accommodate 30 passengers. Other electric hybrid commuter/regional airliners include the ERA by Aura, which is planned as a 19-seater, and the Maeve 01 as an all-electric 44 seater. For completeness, other electric aircraft projects below 19 seats and largely outside the scope of this report include: Eviation Alice (9 seats); Ampaire Tailwind (9 seats); Zunum Aero ZA10 (12 seats) and the Faradair Bio Electric Hybrid (18 seats). Larger capacity projects include Embraer's hybrid electric Energia E19/E30-HE (19-30 seats).

Figure 2.6: Heart Aerospace ES30

Source: Air Insight

Some new technology companies are offering electric propulsion powered by hydrogen. Universal Hydrogen is developing retrofit options on ATR and Dash 8 airframes in which hydrogen capsules are stored in part of the rear cabin such as shown in Figure 2.7. This would involve moving the rear pressure bulkhead forwards and reducing the number of available seats for which the full support of the OEMs would be needed. For example, in the case of the ATR72-600, this would leave 56 seats. By contrast, ZeroAvia proposes to maintain the existing seat configuration and create hydrogen storage capacity in a combination of underwing pods, in the wings and above the fuselage. In addition, following a two-year co-operation between Britten-Norman and Cranfield Aerospace Solutions, both have recently announced a merger to accelerate the development of hydrogen fuel-cell powered B-N Islanders.

Figure 2.7: Universal Hydrogen Storage Capsule Schematic Dash 8-300 & ATR72



Source: Universal Hydrogen

2.2.2 Principal specifications and weights

Current Generation Aircraft

The principal weights and specifications associated with the relevant aircraft are shown in Figure 2.8. Since the capacity of the aircraft has been increased, their full weights have also risen. This impacts both the range and runway performance of the Dash 8 as shown.

Figure 2.8: Specifications Comparison

Variant	AT42-600	AT72-600	ATR72-600	Dash 8-400	Dash 8-400(EC)
MTOW	18,600kg	22,500kg	23,000kg	29,583kg	30,481kg
Max. payload	5,250kg	6,718kg	7,500kg	8,386kg	10,125kg
Engines (2x)	PW127XT/M	PW127XT/M	PW127XT/M	PW150A	PW150A
Range	726Nm	740Nm	740Nm	1,140Nm	740Nm
Take off Distance	1,107m	1,367m	1,367m	1,425m	1,573m
Landing Distance	966m	1,068m	1,068m	1,289m	1,346m
Max Pax Capacity	48	68-72	70-78	78-82	86-90

Differences between standard and high-capacity variants

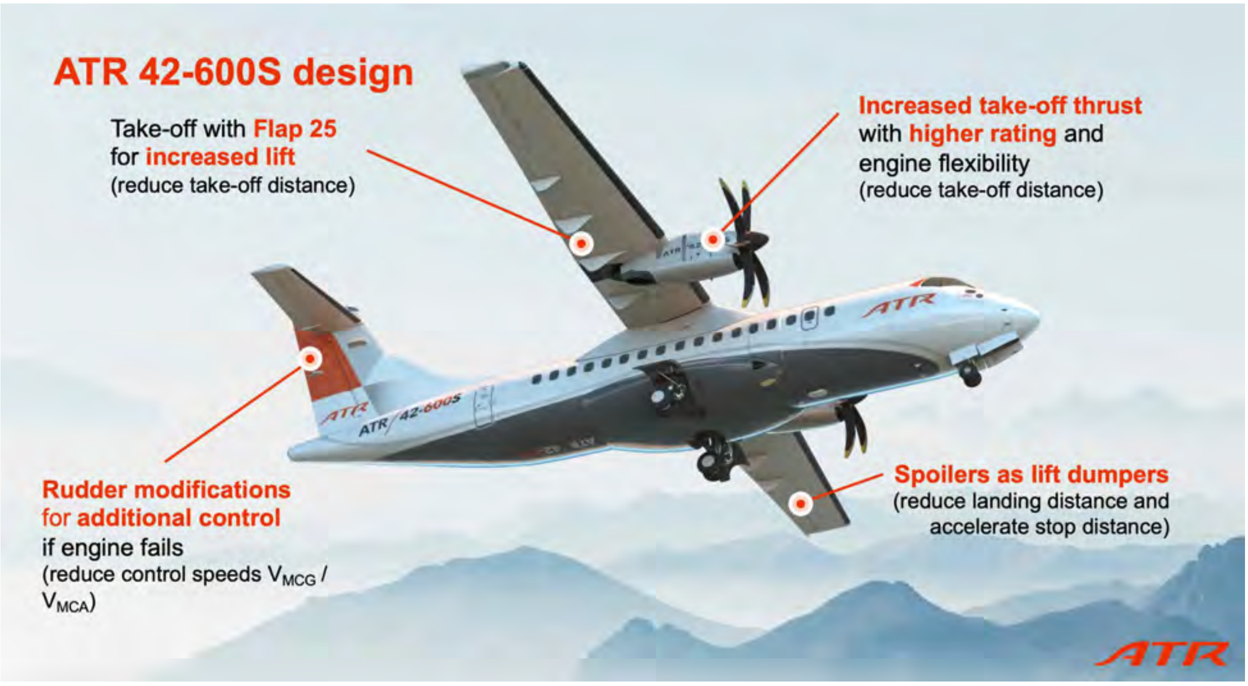
The high capacity ATR72-600 is essentially an upgraded standard aircraft which incorporates higher weight and payload. Although the weight upgrades can also be applied to lower capacity versions, if required, by the operations of individual airlines. Unlike the Dash 8, the high-capacity ATR does not have any range or performance penalties. Although the reduced range performance of the Dash 8 has no material impact on live operations, turboprop services requiring the maximum range offered by that aircraft type are negligible.

ATR42-600S STOL

The ATR42S "Short take-off and landing" STOL aircraft is a new variant of the standard ATR42-600, which will enable it to take-off and land from airports with runways that can be as short as 800m. As there are currently no 30+ seat aircraft that have this performance capability this version is designed to address that market, which is currently only served by ageing out-of-production aircraft such as the Dash 8-100/200. These aircraft are now all above 20 years old and the average fleet age is closer to 35 years.

The ATR42-600S requires several modifications (See Fig. 2.9) including a larger rudder and steep approach capability and will still have payload limitations to 33 passengers on an 800m runway. Payload improves considerably with incremental additional runway length. At 900m the ATR42-600S is limited to 42 passengers.

Figure 2.9: ATR42-600S Modifications



Source: ATR

Future Generation Aircraft

The precise specifications and weights of none of the future generation aircraft have been frozen, but certain aspects have been published beyond the planned passenger capacities.

Preliminary weight estimates for the ES30 the ERA and the Alice are available. The ES30 is expected to have an MTOW of 20-21,000kg (FlightGlobal Sept 2022) and the Aura ERA will have an MTOW of 8,100kg. Its payload is expected to be in the region of 2,000kg. By comparison, the smaller Alice will have a similar MTOW of 8,300kg and a payload of 1,130kg.

Numerous other projects are at a concept design phase both at all major existing OEMs and other new entrants. At the larger end of this spectrum Maeve Aerospace has released preliminary weights for the Maeve 01 all-electric aircraft that is expected to have an MTOW of 45,000kg and a payload of 4,965kg. Note that the MTOW of this aircraft is over double that of the similar capacity ATR42 (Fig. 2.8), which illustrates one of the principal challenges faced by scaling all electric aircraft.

2.2.3 Engines & Future Propulsion

As in previous TrueNoord Insight reports, this section reviews current generation gas turbine engines that power existing airframes. In addition, this report introduces electric propulsion for the next generation of propeller driven aircraft. This is limited to electric propulsion (whether derived from batteries or hydrogen) as the remaining alternative of direct hydrogen combustion is considered to be both further away in time and is applicable to larger aircraft outside the scope of this report.

Current Generation Gas Turbine Engines

ATR72 has always been powered by various derivatives of the PW 120 series. Today's ATR42/72s are powered by the PW127F or M variants. The PW127 is considered a mature engine and is the only remaining 120 series that is still in production. By contrast the competing Dash 8 is equipped with the larger and more expensive PW150 power plant, which has had limited development over recent years. The Chinese manufactured MA700 is also powered by the 150A.

While the PW127 power plant is mature it also has certain disadvantages. On the ATR72, the engine has reached its thrust limit so that it cannot be materially adapted for markets that require a higher performance aircraft. There have been some incremental modifications for hot and high operating conditions with an "N" variant offering a boost function. However, this PW127N variant was only selected by Avianca to enable replacement of the Fokker 50. After leaving Avianca these aircraft are likely to be de-modified as the secondary market prefers the standard "M" version.

As from December 2022, new ATR42/72s will be powered by an upgraded PW127XT engine as discussed in section 2.5 below, but this engine will not enhance the performance of either aircraft. Instead, it will primarily offer maintenance interval and cost advantages as well as an incremental 3% fuel burn benefit over the PW127M. The PW127XT can be retrofitted to existing ATR42/72s and co-mingled with an M engine on the opposite side of the aircraft. The PW127M can also be upgraded to an XT, which only makes sense during a full overhaul.

The principal benefits of the PW150A are that it can power the larger airframe and enables faster climb performance and greater speed (see Fig 2.14). This enables both shorter sector times for the same distance and better performance at restricted airports particularly in hot and high conditions.

However, there are also disadvantages. The faster cruise speed has limited value on typical 45-90 minute sectors by bringing a limited 10-15 minute flight time improvement only. Many airlines do not consider this to be a material benefit. Secondly, the larger power plant consumes more fuel than the PW127 and has considerably higher maintenance costs closer to those of smaller jet engines than to the PW127. To save fuel, many operators have slowed the cruise speed in operation to under 300kts from 360kts as this brings the trip fuel burn closer to that of the ATR72-600. Only by slowing the cruise speed and increasing capacity closer to 90 seats can the Q400 compete with the ATR72 on fuel burn per seat mile (see section 2.6).

Future Generation Powertrains & Fuels

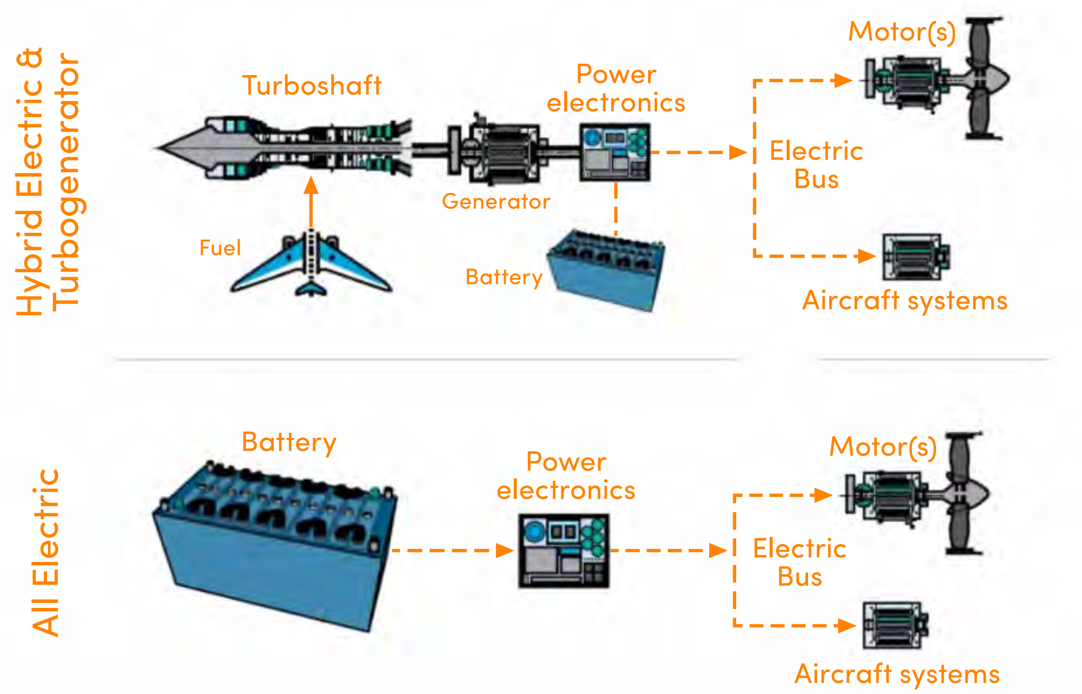
In a perfect world of zero emissions, aircraft of the future would be powered by electric motors from batteries stored in much the same way as conventional fuel tanks in the wings or in the fuselage. While this is the long-term aim, suitable battery technology for large airliners may still be decades away. Current lithium-based batteries have a power to weight ratio that is orders of magnitude less than conventional fuel, so that the required battery weight to generate the same power level as a gas turbine is far too high for any commercially sized aircraft to have a useful range. Battery technology, led by the automotive industry (albeit now as much about cost reduction as performance), continues to develop but is still expected to take many years to reach sufficient maturity and reduced weight for use in all electric aircraft. Given the limitations of batteries two alternative pathways are currently favoured.

All Electric & Hybrid Electric Propulsion

Currently, many aircraft electrification projects are focused on either “more electric systems” in aircraft to reduce the power required from the current engines or hybrid propulsion whereby smaller gas turbines would either be supplemented by electric motors for certain phases of flight or would charge batteries in-flight to power electric motors. While some all-electric propulsion projects including the Maeve 01 are under development the weight of current technology batteries required for a useful mission length means that an MTOW of at least double that of a similar sized conventional aircraft is the result. This is the prime driver that has led Heart Aerospace to pivot to a hybrid propulsion system comprising electric propulsion powered by a combination of fewer heavy batteries and dual turbo-generators.

The “All electric” and “Hybrid and turbo-generator” concepts are shown in Figure 2.10. The hybrid concept shown is “in-series” whereby the conventional engine (turbo-generator) provides electricity to power electric motors. Compared to conventional twin engines, electric propulsion enables efficiency gains by allowing the distribution of power across multiple motors that outweigh the losses associated with converting one form of power to another from the turbo-generators. This has become the system adopted by the Heart Aerospace ES30 and the Aura ERA both of which have multiple motors on each wing.
An alternative parallel hybrid model is where energy to the propulsor is provided by an electric motor and a gas turbine simultaneously. This is the strategy currently favoured by ATR in its EVO project (Fig. 2.11).

Figure 2.10: Hybrid & All Electric Propulsion Schematic



The ATR72EVO announced in 2022 envisages mild hybridisation whereby an electric motor is integrated into a smaller, as yet undefined, engine than the PW127 (Fig. 2.11) to boost power in the take-off and climb phases of flight. In the above referenced “more electric systems” category ATR plans to use electric de-icing in place of boots filled with bleed air from the engines as well as other aerodynamic improvements aimed at reducing the power needed from the gas turbine engines. The net effect would be to substantially reduce the fuel burn and emissions of the gas turbines. ATR have stated that the objective is to reduce fuel burn by some 20% with the EVO.

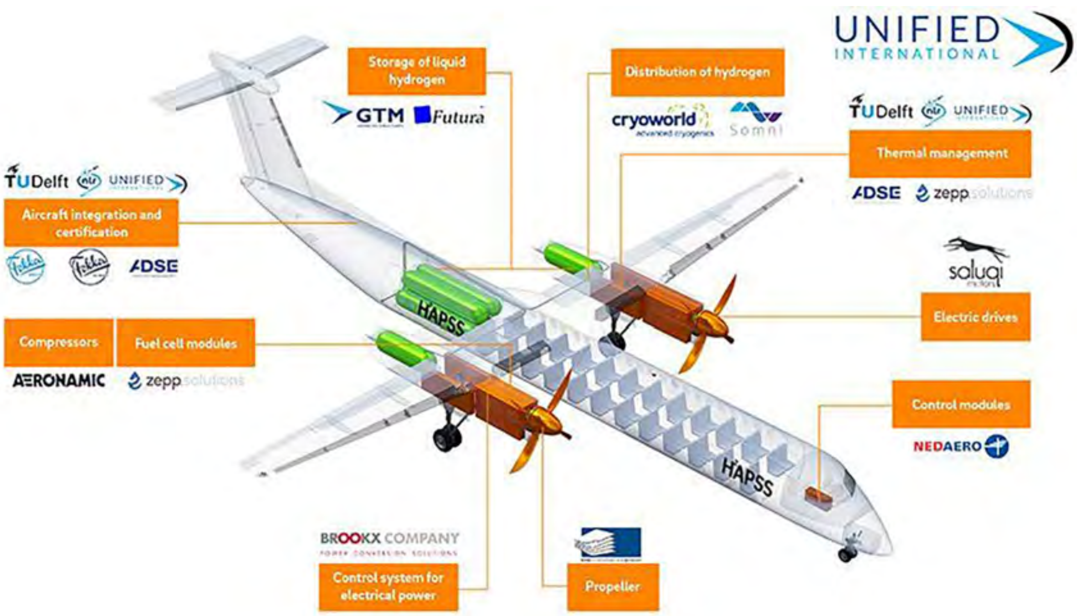
Figure 2.11: ATR42/72 Evo Mild Hybridisation

Source: ATR

Hydrogen Fuel Cells for Electric Propulsion

Electric power can also be generated in a hydrogen fuel cell, which converts hydrogen and oxygen into electricity, which in turn can power electric motors as shown in Figure 2.12. The introduction of a hydrogen fuel cells replaces the need for a gas turbine in a hybrid electric aircraft and confers the benefits of removing traditional engines.

Figure 2.12: Fuel Cell/Battery Hydrogen Powered Propulsion System



Source: Unified International/Innovation Quarter published in "Aviation Week"

Some manufacturers including ZeroAvia and Universal Hydrogen believe hydrogen fuel cell technology is the optimum route forwards. However, hydrogen and fuel cells come with their own remaining technical challenges including limited range, significant heat by the fuel cell, and potential leakage of hydrogen on board and while in flight.

There are also nuances between the architecture of the Universal Hydrogen and ZeroAvia propulsion system.

- The refuelling process differs. Universal Hydrogen loads full capsules onto the aircraft after each flight and ZeroAvia refuels the onboard tanks in a more conventional manner.
- To facilitate loading capsules the Universal Hydrogen system requires their location to be in the fuselage, which means that several rows of seats are sacrificed. In an ATR72 this results in a 56-seat capacity. ZeroAvia stores the hydrogen in under wing pods on its Dornier 228 test aircraft and proposes to house the hydrogen tanks outside the cabin of the ATR72.
- Universal Hydrogen's fuel-cell is planned to provide sufficient power output for all phases of flight including take-off and climb so that no battery boost is required. ZeroAvia's system includes a battery for peak power needs that is then re-charged by the fuel-cell when less power is needed.

Both manufacturers acknowledge that in order for a hydrogen-based propulsion system to be practical, they need to play a key role in the hydrogen distribution infrastructure. This may also include hydrogen production. Accordingly, both manufacturers are proposing their respective refuelling infrastructure as an integral part of their product.

SAF & Other Fuels

Other future fuels include the use of ammonia and Sustainable Aviation Fuel (SAF). SAF is for now the key pathway for the wider aviation industry to reach the necessary climate related goals for medium and long-haul travel as there are no real alternatives. However, since the amount of SAF available for commercial aviation is currently not even sufficient to provide 0.25% of the industry's needs, the expansion of its supply to a materially useful level is urgent. If available at scale, SAF could also address the needs of regional aviation with little change to fuel infrastructure.

Hydrogen can potentially also be combusted directly as a fuel without prior conversion to electricity via a fuel cell. Direct combustion is currently believed to be more suitable for larger aircraft while fuel cell conversion is widely understood to be better for smaller regional aircraft. Consequently, the large aircraft OEMs are more focused on direct combustion and so these developments are outside the scope of this report. However, the supply of hydrogen is also very limited and necessitates the development of new fuelling infrastructure in addition to dramatically increased supply.

ZeroAvia

2.3 Range

Current Generation Aircraft

In its current standard configuration, the range of the ATR72-600 at 740nm with a full load is some 400nm less than the Dash 8-400. However, as a range in excess of 1,000nm is very rarely a mission operated by any turboprop aircraft this capability is of limited practical value. Most turboprops operate sectors of less than 400nm and generally the optimal sector length is in the region of 200-300nm. Accordingly, the range penalty of adding up to 12 seats in the Dash 8-400 EC version is minimal for the vast majority of missions.

The ATR42-600 is predominantly used for even shorter sectors than its larger sibling or the Dash 8-400. It therefore has more than adequate range capability (726nm). However, in its STOL version its range will be limited according to runway length. On an 800m runway its range will be limited to 200nm with a maximum of 33 passengers and 300nm on a 920m airfield length with a full passenger load.

Future Generation Aircraft

Although battery technology is both advancing and is likely to continue to do so, the current state of power storage is such that pure electric aircraft have limited range even with a fourfold increase in energy storage capacity per kg. Figure 2.13 shows that the range capability of aircraft on battery power only is likely to be limited to not much above 200nm. While useful this would enable, for example, the ERA to cover about 60% of sectors worldwide that are currently served by 30-50 seater turboprops. In the case of the ES30 this would reduce to about 30% of this segment.

In order to increase range and reduce the heavy weight of the batteries both the ERA and the ES30 have adopted a hybrid architecture whereby two turbogenerators will be fitted to the rear of the aircraft. These will enable the batteries to be charged inflight to extend their range to enable a larger addressable market. Such a dual installation is necessary to provide redundancy as a single unit would mean that both aircraft would be considered as single engine aircraft for missions that rely on power from the turbogenerator.

However, the addition of turbogenerators does mean that neither aircraft can be considered as a zero emissions product. Furthermore, the certification process for inflight power that is not operational from take-off is not yet clear.

Figure 2.13: Future Generation Aircraft Range

	All Electric	Hybrid Electric & Turbogenerator	H2 Fuel Cell
Universal Hydrogen	NA	NA	550nm
ZeroAvia	NA	NA	500-1,000nm
Aura ERA	215nm	1,000nm	NA
Heart ES30	108nm	216nm	NA
Maeve 01	250nm	NA	NA

For the hydrogen powered retrofits the expected range is in the same region as the current gas turbine powered aircraft to enable at least the same missions.

2.4 Performance

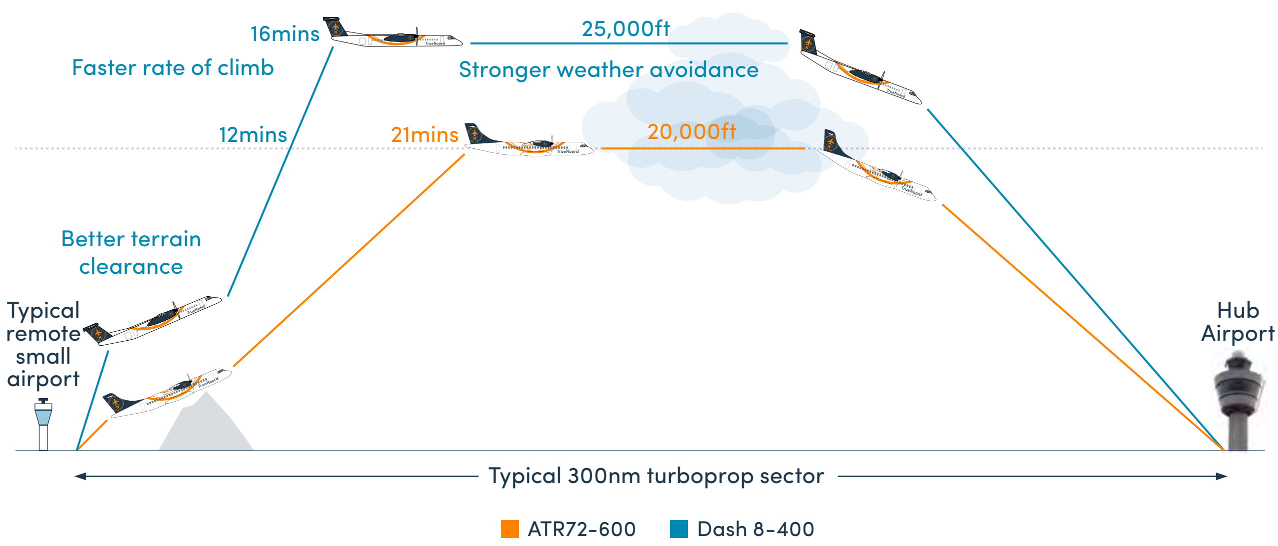
The ability to operate from restricted airports with short runways or in built-up areas is often a key attribute of regional aircraft. Typically, this favours turboprops over regional jets. However, although both large ATR72 and Dash 8-400 turboprops offer superior performance characteristics on short runway airports compared to jets, both aircraft were primarily built to offer increased capacity and competitive operating costs thereby compromising some potential performance capabilities.

While neither large turboprop aircraft is a STOL performance aircraft capable of taking off from runways shorter than 1,000m, both can nevertheless achieve a respectable 1,300m take-off field length, which is sufficient for most restricted airports that require high-capacity turboprops. However, several hundred airports with shorter runways exist in remote areas or mountainous terrain. These can only be served by STOL aircraft such as the Dash 8-100/200 both of which are now out of production. The ATR42-600S referenced in 2.2.2 is aimed at this market. Although a large part of the world's STOL airports are adequately served by smaller capacity 19 seat aircraft including the De Havilland Twin Otter or Dornier 228, some do require the capacity offered by aircraft of this size.

Climb performance is also important where physical obstacles exist, such as high-rise buildings in cities or mountainous terrain, as well as those areas where it is both hot and high. For example, while the ATR72 can operate from London City airport the superior single engine climb performance of the Dash 8 enables it to operate optimally from there. Strong climb performance can also be important to meet local area noise restrictions.

In the 300nm illustration in Figure 2.14, a 300nm mission profile from a remote airport to a major hub is shown where the ATR72 takes 21 minutes to reach 20,000ft compared to 16 minutes for the more powerful competing Dash 8. The trip time for the Dash 8 at high-speed cruise (360kts) is 57mins and 73mins for the ATR72 at 270kts. Not only can this provide the bad weather avoidance as shown but is critical in hot and high areas such as Kenya, Ethiopia and parts of South Africa where the ATR72 struggles to perform the required missions and the Dash 8 is the favoured option. However, the performance benefit of the Dash 8 comes with an operating cost penalty compared to the ATR72 in the form of increased fuel burn and maintenance costs although this remains less than for similar sized jet aircraft (see section 2.5).

Figure 2.14: ATR72-600 v Dash 8-400 Performance



Source: TrueNoord Intelligence adapted from Flying Engineer

2.5 Economic Comparison

The elements of operating costs, apart from the aircraft capital portion, are often referred to as Cash Operating Costs (COC). The elements that are driven by the aircraft itself are briefly reviewed below. Crew costs are a major COC component but are not reviewed as these are broadly the same for any similar capacity regional aircraft. (Note that crew costs for regional airlines are typically lower than those of mainline carriers, particularly in the U.S.) Similarly, navigation and landing charges are not reviewed as these are largely driven by aircraft weight in many parts of the world. The ATR72 is lighter than the larger Dash 8 in both absolute terms and on a per seat basis.

With respect to new technology aircraft there is, as yet, insufficient data available to make a meaningful comparison with current generation aircraft. At a general level:

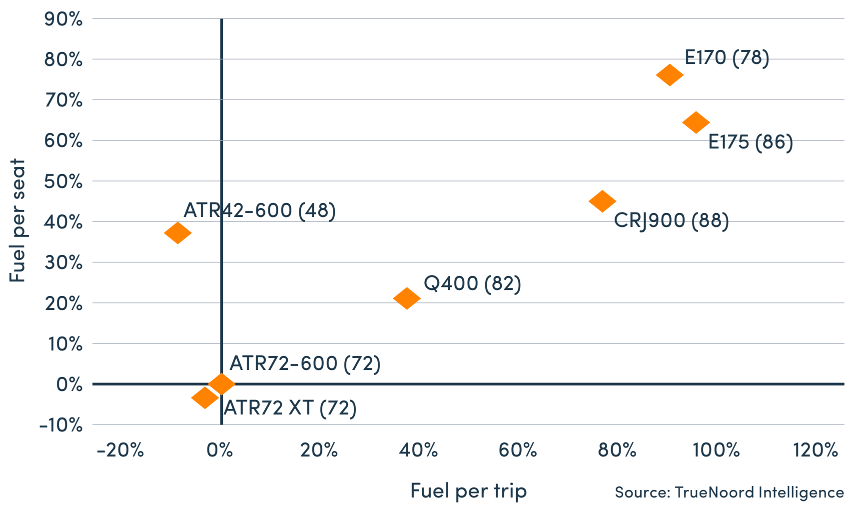
- The fuel costs for all electric propulsion systems should be substantially less than jet fuel, but hybrids will continue to use some amount of conventional fuel. Eventually, as hydrogen production is scaled, its cost should reduce.
- In the long-term many expect the cost of jet fuel to increase, even before the application of carbon emissions surcharges, which would shift the energy cost in favour of alternatives.
- Maintenance cost breakdowns are likely to look substantially different although the overall cost may or may not end up as more attractive. For example, current technology battery life is expected to be in the region of 2,000FC, which means these would need changing every 1-2 years of service. (Note these high-capacity batteries can be recycled or repurposed for ground-based power storage). Furthermore, maintenance workscopes in next generation aircraft will not be grouped into airframe and engine tasks. Aircraft of the future increasingly comprise a whole system in which the electric motors are a relatively small component.
- It is likely that an incentive to decarbonise will include reduced navigation and airport fees so that any future COC comparison will need to include this element, which heretofore are similar and cannot be materially impacted after a current generation aircraft type has been chosen by any given operator.

2.5.1 Fuel Burn

The ATR72 has generally been considered to have lower operating costs than any of its competitor aircraft in a similar seat capacity. In the example shown in Figure 2.15, the ATR72 burns some 850kg compared to 1,170kg for the Dash 8, which represents a substantial 38% difference in the trip cost, this reduces to 20% on a per seat basis. However, at this fuel burn the Dash 8 has a substantial speed advantage over the ATR by completing the journey 9 minutes faster and only a few minutes slower than the regional jets. In practice some Dash 8-400 operators prefer to reduce fuel burn with a slower cruise speed closer to that of the ATR72, which can erode the difference by around 50%.

Nevertheless, the ATR72-600 still has the lowest fuel burn of any regional aircraft on both a trip and a per seat basis at this sector length. As the trip length increases (not shown), the faster speed of both the Dash 8 and the regional jets begins to erode the fuel efficiency of the ATR72 so that the fuel burn advantage against the Dash 8 reduces to under 20% on a per seat basis and under 50% for the regional jets.

Figure 2.15: Block Fuel Relative to ATR72-600 (300nm at US$0.90/kg fuel)



Source: TrueNoord Intelligence

IndiGo

TrueNoord Fleet
5 ATR 72-600

The ATR72-600 not only offers strong fuel efficiency benefits against regional jets, but also competes favourably with mainstream single aisle jets where only the newest generation B737MAX and A320Neo offer similar or better fuel consumption per seat on short sectors. However, the large jets do offer greater efficiency on sector lengths above 500nm.

As the CRJ and E-Jet families are both mature aircraft programmes, there is a wealth of data available from the manufacturers (including the engine OEM), as well as direct experience from the TrueNoord fleet. Therefore, a combination of OEM data, which has been cross checked with TrueNoord's own internal experience, has been applied. As a consequence, the scheduled tasks and hard time intervals are reasonably accurate, but the associated costs are estimates, which have been slightly escalated to be conservative unless an actual published figure is used, as is the case with engine LLPs.

2.5.2 Maintenance Costs

As the ATR72 and Dash 8-400 are both mature aircraft there is strong base maintenance data available from the manufacturers (including the engine OEM) and third party maintenance shops. The cost estimates represent early 2023 data and are expected to increase due to cost escalation that is expected to continue to be high because of ongoing inflationary pressures. The principal scheduled maintenance tasks, intervals and estimated costs are as follows:

Figure 2.16: Maintenance Comparison ATR72-600 & Dash 8-400

ATR 72	Dash 8-400
Airframe Checks (FH & FC)	
Airframe maintenance heavy check (C-check) currently has an 8,000FH interval which has recently been escalated from 5,000FH. The estimated average C-check cost is approximately US$5-20 per FH assuming that the event cost will not increase due to the greater interval. Note that the increased interval may mean that the amount of tasks may increase and therefore the event costs may be higher.	Airframe maintenance heavy check (C-check) intervals are 8,000FH. The estimated average C-check cost is in the region of US$30-35 per FH.
Airframe Calendar Checks	
In addition, there are calendar-based inspections at 2, 4 and 8 years and a major structural inspection at 36,000 cycles. The average cost of each 2-year interval check is estimated at US$9-10,000 per month. The 36,000 cycle cost is currently estimated at around US$15 per FC Historically, calendar checks aligned reasonably well with C-check intervals, but since these have been escalated these can be out of phase thereby adding to both downtime and cost.	In addition, there are calendar based inspections at 6, 9 and 12 years with associated average costs of around US$8,000 per month respectively and a major structural inspection at 40,000 cycles at an estimated cost of US$7.50 per FC.
Landing Gear **After the engines, the landing gears are the single most expensive items on any turboprop aircraft and both aircraft have gear related issues**	
Overhaul limits are 20,000 FC or 9 years. After the engines, the landing gears are the single most expensive items on any turboprop aircraft Average overhaul costs are in the region of US$6,000 per month.	Overhaul limits are 20,000 FC or 12 years for the nose gear and 30,000 or 12 years for the main gear. Average overhaul costs are in the region of US$5,000 per month.

Engines

While engines are maintained on-condition, the time on wing prior to any hot section inspection varies considerably according to the operating environment and can on average vary between about 7,000 hours in benign conditions to as little as 4,000 in, for example a sandy harsh environment. Accordingly costs can vary between USD$90-130 per engine FH. On average every second HSI requires additional overhaul/refurbishment tasks to be performed due to the higher level of disassembly required to replace LLPs (especially for HP Impeller) that also increases the total shop visit cost by around US$40 per engine FH excluding the LLP costs themselves. The engine's reduction gearbox module which is usually overhauled simultaneously with refurbishment of the turbomachinery module will add US$12 per engine FH. For the PW127XT the manufacturer states that on-wing times will be about 40% longer and the HSI and refurbishment costs are expected to be greater so that the overall cost saving per FH would be in the region of 20%. However, only experience will show how well this engine behaves in practice, especially in harsh environments.	While engines are maintained on-condition and similarly to the 127 series, the time on wing varies considerably according to the operating environment. Typically, inspections are required between 4,500 and 7,000 FH so that the cost can range from US$175 to well in excess of USD$200 per engine FH. The reduction gearbox, usually overhauled simultaneously with the refurbishment of the turbomachinery module will add about US$30 per engine FH.

Engine Life Limited Parts (LLPs)

P&WC, the engine OEM, often refers to LLPs as Low Cycle Fatigue parts life (LCFs)

LLP or LCF life costs are estimated to be in the region of US$30 per engine FC. The majority of LLPs have a 15,000 FC ultimate life limit and the cycle rate includes PW&C's and shop discounts. On the PW127XT all LLPs that have a 15,000 FC limiter are increased to 20,000 FC. Nevertheless, the cost per FC will be in the region of US$37 per FC.	LLP or LCF life costs are estimated to be in the region of US$37 per engine FC. The majority of LLPs have a 20,000 FC limit except the HP impeller at a lower 15,000 FC.

Propeller

Propeller hubs and blades have a hard time limit of 10,500 FH or 7 years. The estimated costs are around US$28 per engine FH. In practice, the blades commonly need repair or replacement before that.	Propeller hubs and blades have a hard time limit of 10,000 FH. The estimated cost is at around US$23 per engine FH. In practice, as with the ATR, blades commonly need damage related replacement before that.

APU

The ATR has no APU. Instead a propeller brake system allows the right hand engine to be operated in "Hotel" mode to provide ground power when needed.	While maintained on condition, the APU is estimated to have a shop visit at 5,500 APU hours at an estimated cost of US$44 per APU hour.

Comments on Maintenance

The above maintenance costs and intervals are based on fixed intervals except for engines, which are maintained on condition. The actual maintenance costs will vary considerably according to how the aircraft are operated and the environments in which they fly. For example, in harsh climatic environments the ATR is often less robust than Dash 8 aircraft and additional findings at major events can often increase the maintenance costs significantly.

Regarding engines there is considerable disparity between benign and harsh climates with several historical examples of engine removals below 5,000 FC in less favourable environments.

ATR42-600 Maintenance Cost Differences

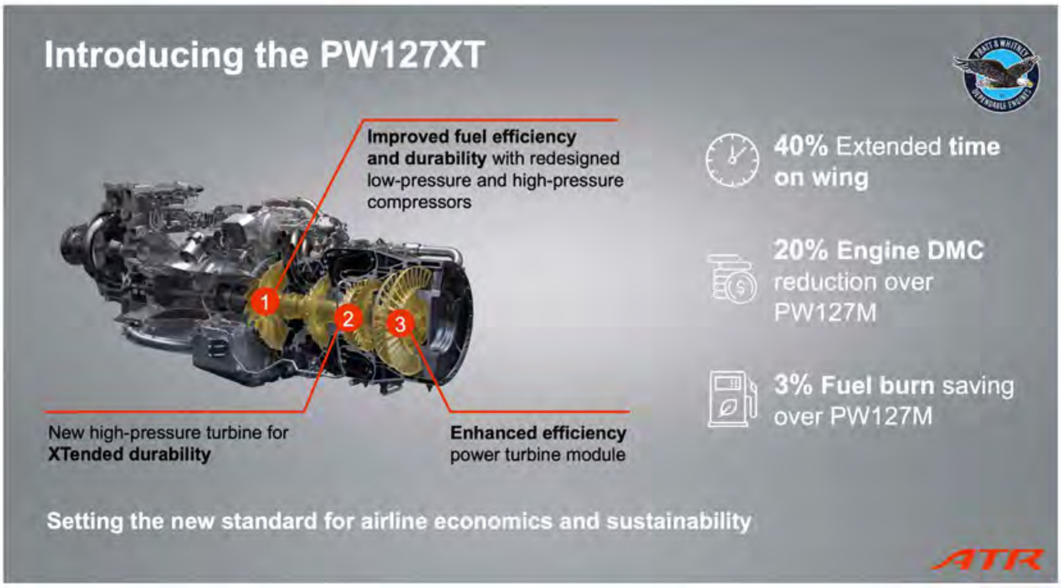
Despite the lower capacity, weight and thrust rating for its engines, its maintenance intervals and associated costs are not significantly different to those of the ATR72-600. Both FH driven and calendar driven airframe costs are no more than around 5% lower than those of the larger aircraft. With regard to engines, the lower thrust requirement for the aircraft relative to the ATR72 would be expected to lead to longer on-wing times.

PW127XT Engine Upgrade

According to ATR and P&WC the new XT engine, the first of which were delivered to Air Corsica in late 2022, promises significant maintenance cost reduction benefits not in terms of event costs, but rather in additional on-wing time of up to 40%. Increased on-wing time generates cost savings related to the frequency of required shop visits, but the event costs also increase. Accordingly, P&WC estimates that the actual maintenance cost reduction over time is in the region of 20%.

The principal changes over the PW127M shown in Figure 2.17 relate to many of the durability issues that have affected the higher rated PW120 series engines since inception. It also features durability improvements on many of the life limited parts. This includes redesigned high and low pressure compressors and turbines as well as an enhanced power turbine module at the rear.

Figure 2.17: Future Generation Aircraft Range



Source: P&WC and ATR

2.6 Discussion of Performance & Economic Comparison points

Both the ATR72-600 and the Dash 8-400 have operating costs that are lower than equivalent size category regional jets per trip, but the difference is smaller on a per seat basis. The ATR72-600 has a number of benefits over its principal competitor the Dash 8-400, but the latter also has some advantages:

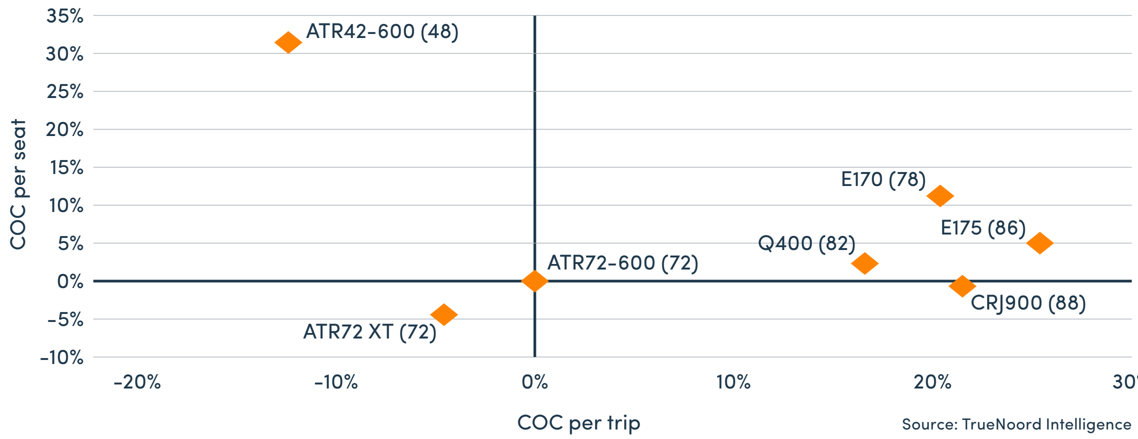
ATR72-600

- The ATR72 has best-in-class operating economics despite its smaller size. In relation to operating costs - particularly for fuel burn, weight-based airport charges, and maintenance costs - the cash operating costs per available seat of the ATR72-600 have, to date, been better or equal to those of the Dash 8. Therefore, the majority of turboprop operators that do not require the enhanced performance of the Dash 8 have opted for the ATR. Figure 2.18 shows the cash operating costs, which exclude capital costs for the aircraft. This shows that ATR72-600 remains the most attractive turboprop for most markets.
- The exception are those areas where superior performance characteristics mainly in terms of climb and operational ceiling are needed (see Fig 2.14). This is important for those carriers operating at inner city obstacle restricted airports, mountainous regions, or hot and high climates. For example, this drove carriers such as Widerøe in Norway to select the Dash 8 aircraft and some African airlines, such as Ethiopian, to have done likewise.
- The ATR72 has now developed a high capacity 78 seat variant, which is well adapted to competitive Asian regional markets in particular. Based on operating economics, the ATR is the undisputed leader across Asia.
- The ATR72 can be most efficiently applied to markets requiring a capacity of up to 78 seats whereas the Dash 8 is only optimised from a capacity perspective for routes where a capacity from 78-90 seats is required and where regional jets either cannot be operated or are economically inefficient.

Dash 8-400

- The Dash 8 has a faster cruise speed that enables it to compete with regional jets or more effectively complement them. In regions where sector lengths can be long such as certain North American markets this can favour the Dash 8 and provide greater operational flexibility.
- In practice, some operators have not selected the Dash 8 for its speed benefit, but for the extra capacity and a more jet-equivalent product. These carriers often operate them at a slower long-range cruise (approx. 300kts) to minimise fuel consumption.
- The stronger performance characteristics of the Dash 8-400 make the aircraft more suitable for restrictive environments including hot and high terrain.
- However, although Dash 8-400 production has been paused, a 90 seat EC version of the Dash 8 operates at SpiceJet with 12 additional seats compared to the ATR. This means the seat costs of both have converged.

Figure 2.18: Direct Operating Costs Relative to ATR72-600 (300nm sector at US$0.90/kg fuel)



Source: TrueNoord Intelligence

2.7 Emissions

Prior to the COVID-19 pandemic, aircraft emissions had already become a major industry concern and this has now returned to the forefront. As the principal concern relates to CO_2 emissions, Figure 2.19 shows carbon emissions for the subject aircraft on a per seat per nm basis over a 300nm sector. For each aircraft the number of seats from which the per seat calculation is derived is also shown. Carbon emissions are a function of fuel burn. For each kg of fuel consumed, a hitherto generally accepted multiplier of 3.16kg of CO_2 per kg of fuel is applied (Source: ICAO). However, this multiplier is based upon emissions generated by burning fuel only and ignores those generated from extraction of that fuel and processing to its usable form. This can be described as "tank to wake" related emissions.

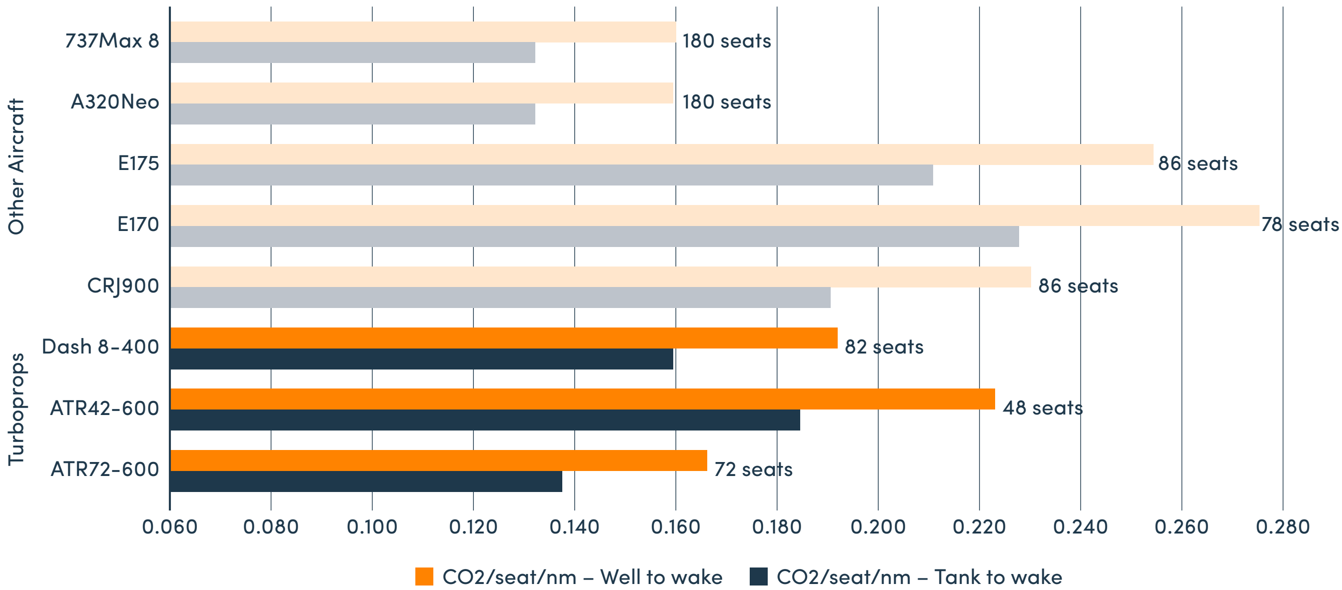
An alternative approach to measuring emissions that includes the impact of extraction, refining and transport of fuel to where it is needed is increasingly attracting favourable attention from both industry stakeholders, policy makers and climate action organisations alike. In an aviation context this means adopting a higher multiplier of 3.83kg of CO_2 per kg of fuel. Both approaches are shown in Figure 2.19 and the latter is described as "well-to-wake" emissions.

While the well-to-wake approach leads to higher emissions it does have a number of benefits for comparative purposes:

- When Sustainable Aviation Fuel (SAF) is introduced in meaningful amounts, the production emissions can be appropriately accounted for according to the different types of such fuel.
- For alternative future fuel types including electricity and hydrogen their production and distribution related emissions can be included (for example, electric power involves few emissions, but its production unless from renewables may not).
- Where emissions from flying are compared to other forms of transport where the source of the power is often disaggregated from its production emissions (e.g. electric power for trains) only a well-to-wake equivalent approach can yield comparable results.

As is evident from Figure 2.19, turboprops have relatively low emissions per seat per km compared to similar sized regional jets reflecting the lower fuel burn of the propellor driven engines as previously discussed in section 2.5.1. Furthermore, on short sectors of up to around 250-300nm, the ATR72-600 in particular has similar emissions per seat compared to the newest generation A320Neo and 737Max aircraft. In Europe, where average sector lengths are shorter than North America, such a 300nm sector is more typical so that in some cases greater frequency can be offered with a 70-seat turboprop without materially compromising operating economics or emissions. On longer average sectors, the speed differential erodes both the economics and passenger acceptance of the turboprops so that in much of North America jet aircraft are generally preferred.

Figure 2.19: C02 Emissions in kg Per Seat Per nm (300nm Sector)



Source: TrueNoord Intelligence & IBA

For new technology aircraft under development no fuel burn or emissions data is yet available although most of the impetus for future aircraft designs is driven by the desire to reduce or eliminate harmful gases. An all-electric aircraft would have zero emissions if the tank to wake equivalent measure was adopted, but unless all the power came from renewable sources, it would not be zero carbon.

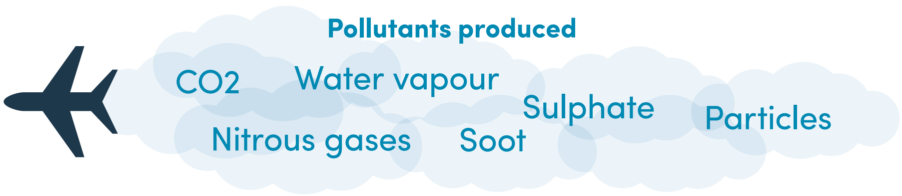
While full electric aircraft would have the lowest emissions, technology readiness levels are such that beyond small short-range aircraft, this option for commercial airliners remains decades away. This is why new technology manufacturers including Heart Aerospace and Aura are proposing hybrid solutions that achieve substantially reduced emissions. By introducing two small gas turbine engines to charge the batteries in flight, emissions would arise in the later phases of flight beyond a short range. Both believe their respective hybrid products will enter service during the current decade.

An alternative potential solution to the technology issues surrounding pure electric regional aircraft is hydrogen as an energy source to generate electricity in fuel cells.

Non-carbon Emissions & Contrails

The prime focus of emissions in all industries relates to carbon, but other harmful gases are also produced including from aviation. These are illustrated in Figure 2.17 and are usually not adequately accounted for in most emissions calculations.

Figure 2.20: Emissions from Air Travel



Source: IPCC

In addition to nitrogen oxides, which have both a warming and a cooling effect, but a net warming influence, particles including hydrocarbons, soot and sulphates are generated. Newer generation engines emit far fewer particles than earlier models, but their effect remains substantial. When aircraft fly at cold high altitudes above 30,000 feet in humid air that is supersaturated in water with respect to ice those solid particles trigger a cloud formation. The contrail clouds that are generated usually dissipate over a short period but can last up to 24 hours. Even though these have a short life span they do have a significant warming effect which is more potent at night when outgoing earth radiation is trapped under the formed cloud cover.

If the effect of non-carbon emissions and contrails are converted to an equivalent of carbon dioxide effects, the total impact increases substantially. Contrails form the largest part of this additional effect. However, these contrail effects are absent from the ATR72 because its operating ceiling is 20,000 feet, an altitude at which contrails are not formed. The Dash 8-400 is limited to 25,000 (see Fig. 2.14) feet where contrails are also generally not formed. Relative to other commercial aircraft, this further enhances the environmental performance of turboprops.

3 Market Review

While the following market review maintains the same structure as the previous aircraft turboprop report in 2020, this version has been prepared in the context of the post COVID-19 situation, current geopolitical and economic events, and the current important drive to improve if not eliminate the environmental impact of aviation. This necessitates a different emphasis within certain sub-sections and also addresses the fact that it is not necessarily possible to draw similar conclusions from the empirical data shown. It also includes a new introductory section 3.1, to explain the role of turboprops within the global air transport ecosystem.

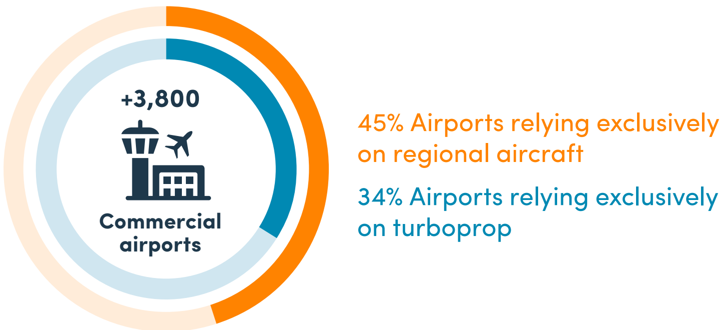
Furthermore, this section broadens its scope to include current generation turboprops to include the in-production ATR42 series. As there is no operator base for new technology aircraft this market review section only covers this segment where relevant and introduces limited references to older generation 19-50 seat turboprops where applicable.

3.1 Deployment of Turboprops

In order to understand the position and demand for turboprops in the short-haul air transport ecosystem the optimal role of this size and type of aircraft can be summarised as serving:

- Short sectors up to a stage length of up to 300nm where the flight time difference between operating a jet and turboprop service is less than about 15 minutes. While some turboprops do operate longer sectors, the proportion of turboprop services compared to jets reduces dramatically. In 2022 the average turboprop sector was under 200nm.
- Destinations where the airports cannot accommodate jet aircraft due to short runways, obstacle clearance, or hot and high operating restrictions.
- According to ATR's Turboprop Market Forecast 2022-2041, some 1,290 commercial airports out of 3,800 can only be served by turboprops.

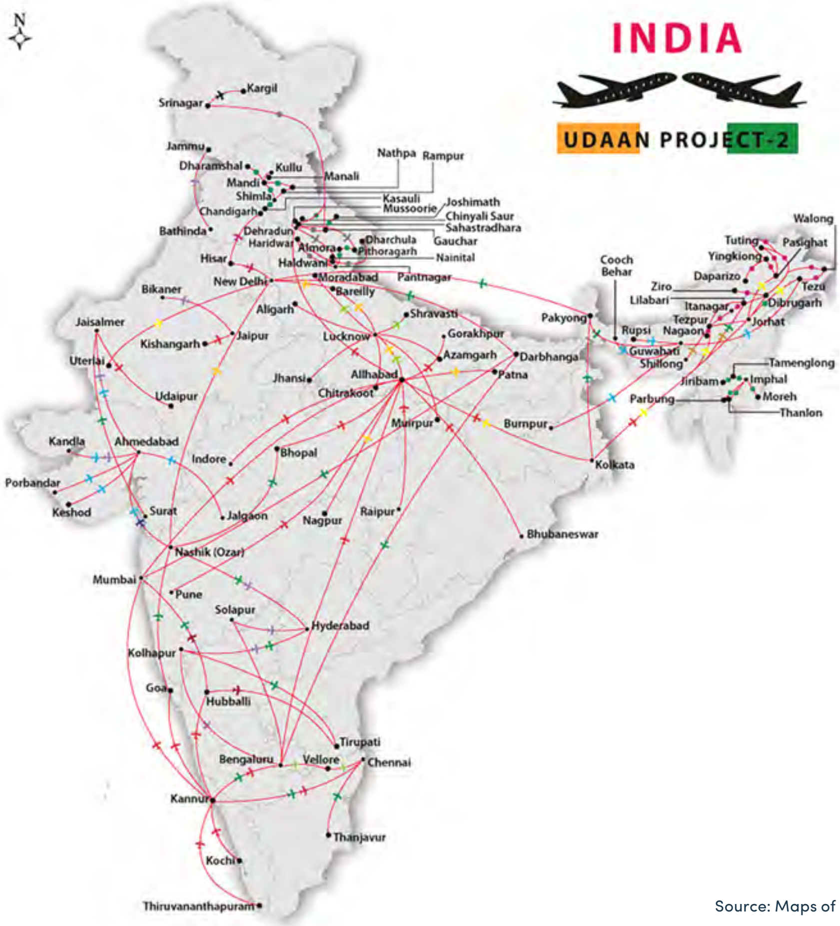
Figure 3.1: Commercial Airports served by Turboprops



Source: ATR

- Markets where passenger demand is such that the capacity provided by regional jets or larger narrowbody aircraft cannot be justified. Typically, routes where the subject turboprops are ideally suited are those where demand is less than about 100 Passengers per Day Each Way (PDEW).
- Markets with thin demand that could justify a larger aircraft if a single daily frequency or less provided a sufficient service level, but where at least a double daily frequency better serves the demand. This could include markets with a significant portion of business travellers who require a same day return service or markets where greater frequency enables more connections at hub airports.
- Markets where yields render the operation of a similar capacity regional jet uneconomic. As shown in Figure 2.15, the operating costs of an equivalent size regional jet are significantly greater that those of a turboprop.
- Routes that are deemed necessary as a public service that would not be economically viable without national or local government support. In Europe these are referred to as Public Service Obligation (PSO) routes. There are some 170 such routes in Europe to remote destinations. One of the most extensive PSO networks is in Norway. Others include many services to Greek islands and those off the coast of Scotland and inter-island services in the Canary Islands or the Azores. In the US, such routes are covered by the Essential Air Services (EAS) programme.
- Similar, and in some cases even more extensive, programmes exist in developing countries including Indonesia (PERINTIS) and India under the Regional Connectivity Scheme (RCS-UDAN) which now has the world's most extensive publicly subsidised network. (Fig. 3.2 shows the pre-COVID status in 2020. There are 419 approved routes in 2022 of which a small proportion are operated by helicopter.)

Figure 3.2: Publicly Supported Regional Connectivity Scheme Routes in India 2020



Source: Maps of India

Figure 3.3: Aer Lingus Regional Network

Source: Great Circle Mapper

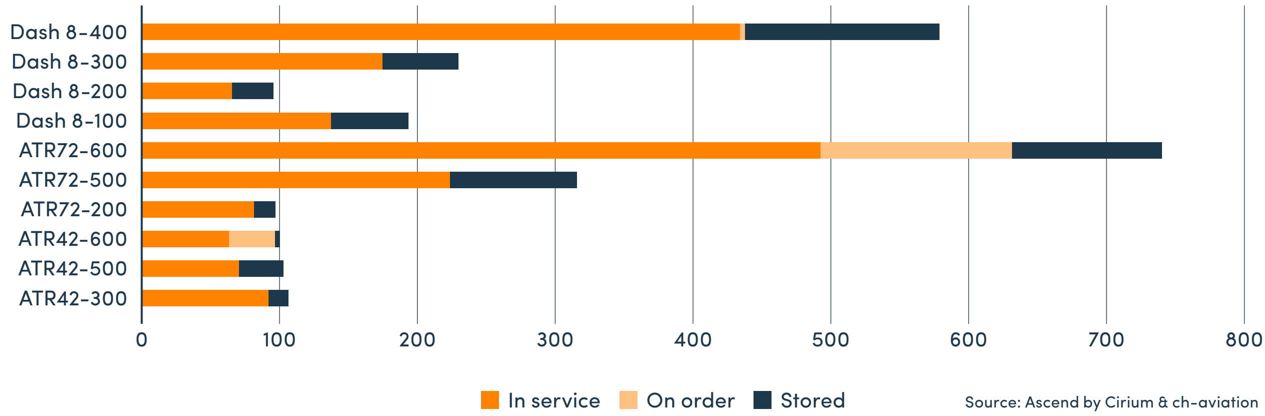
- Some airlines also operate turboprop aircraft to feed their respective hubs. For example, Aer Lingus Regional operated by Emerald Airlines feeds its Dublin transatlantic network with ATR72-600s from most UK airports outside the London area as shown in Figure 3.3.
- Others including Iberia Regional feed Madrid from smaller domestic airports, but also feed with regional jets from further afield.
- However, feeding hubs is more commonly done with regional jets in most of the world particularly where the sector lengths from secondary or tertiary cities can often exceed 500nm.

3.2 Numbers in Service Update

The total number of ATR72s in active service of all variants is currently around 800 units. The latest -600 has been the most successful with 492 in active operation at the end of 2022 considering its relatively short history since 2011. The smaller ATR42 has a worldwide population of 226 active units. The breakdown between the various models is shown in Figure 3.4.

In comparison, the status of the competing Dash 8-400 fleet is also shown in Figure 3.4 and this includes all variants of that aircraft since it was launched in the late 1990s. For in service aircraft, the ATR72-500/600 now leads the Dash 8-400 by around 300 units and the ATR72-600 on its own now leads the entire Dash 8-400 fleet.

Figure 3.4: ATR42/72 & Dash 8-100/200/300/400 Population (Dec 2022)

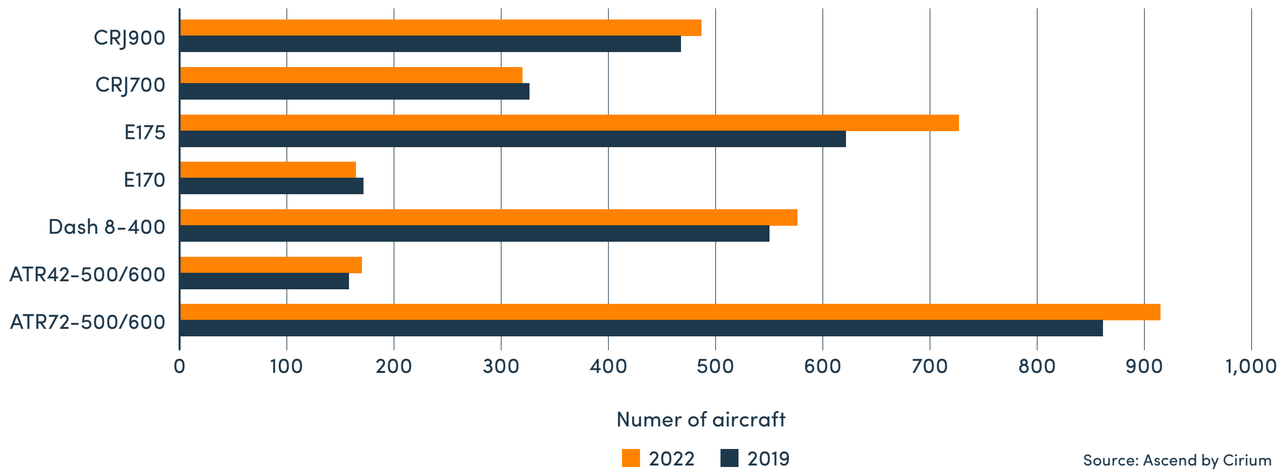


Source: Ascend by Cirium & ch-aviation

When compared to all aircraft types with a capacity of between 70 and 90 seats the ATR72 and Dash 8 populations, including stored units, look respectable compared to similar regional jets. In the case of both ATR and Bombardier, the turboprop fleet size of each exceeds comparable capacity regional jet populations as shown in Figure 3.5 except for the E175, which has proved highly successful mainly in North America.

Needless to add, for the new technology aircraft types, none are yet in service and none are expected to be delivered over the next few years.

Figure 3.5: ATR72-500/600 & Dash 8-400 Fleet Size v Similar Regional Jets (Dec 2019 & 2022)



Source: Ascend by Cirium

3.3 Delivery Profile

The delivery profile of relevant turboprops is an important consideration as it enables the age of any proposed aircraft acquisitions to be compared with the population of aircraft manufactured. In general, more recent vintages are considered to be more attractive to the used market so that younger aircraft should facilitate easier future placement opportunities and premium lease rates. However, in the used turboprop market there are also a number of operators that are age agnostic. In such cases, they may prefer to compare aircraft available based on a combination of their maintenance status and the cost of acquiring or leasing the aircraft.

As shown in Figure 3.6 the ATR72 delivery profile peaked in 2016 and has trended downwards thereafter. From 2016 this reflected both production capacity with increased ATR42-600 output as well as fewer ATR72s to correct a level of overproduction to lessors of units that occurred in the two preceding years. This had already created a mildly soft market for the type in subsequent years which ATR addressed by a significant production rate cut from over 70 units to an average of 60 per year through to 2019. Thereafter, the onset of COVID-19 led to a delivery rate of only 10 aircraft in 2020. Meanwhile ATR42-600 production had increased steadily to 2019 before dropping to a single unit in 2020.

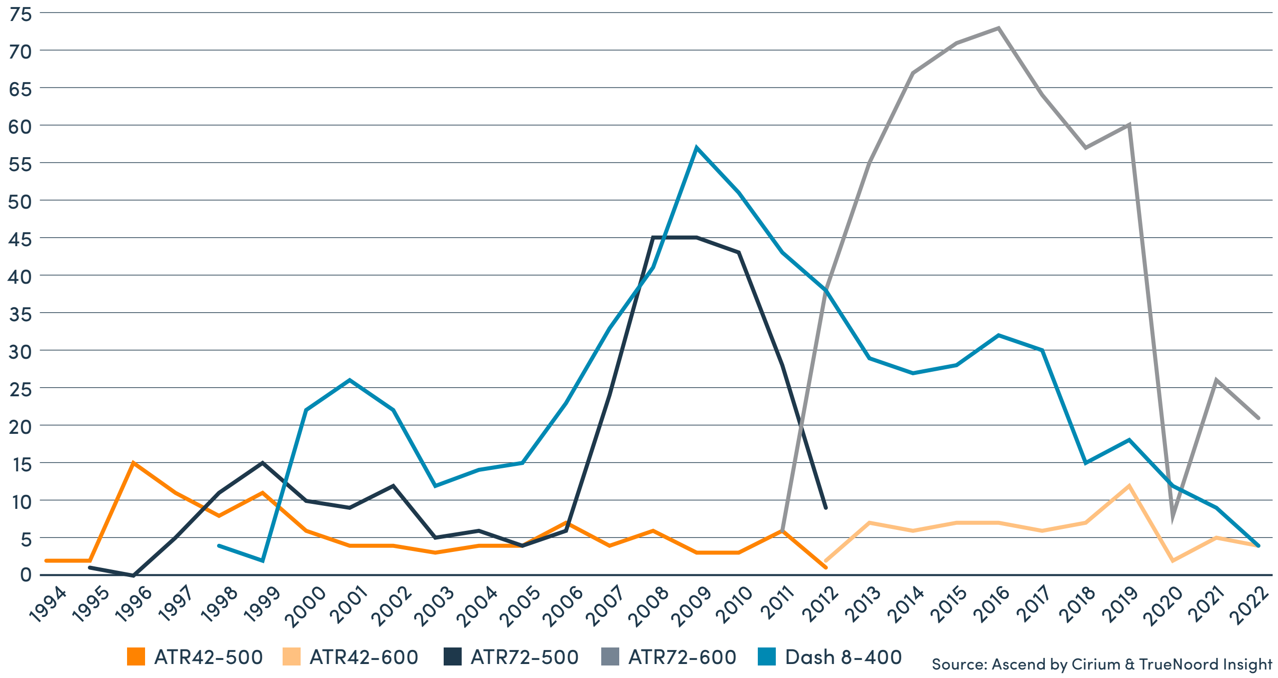
Figure 3.6 also depicts the delivery profile of the Dash 8-400, which shows that aircraft leading deliveries until 2011, after which the ATR has outperformed the Dash 8 by more than 2:1. This reflects the greater importance of competitive operating costs in the Asian market, which is now ATR's largest market in comparison to the previously dominant North American market where the Dash 8 has the biggest market share.

The onset of COVID-19 led to a dramatic fall in deliveries driven as much by an inability to finish the manufacturing process and accept aircraft due to the inability to travel, as much as any short-term lack of demand for the additional or replacement capacity.

ATR deliveries recovered in 2021, but to a much lower level than previous years partly due to subdued demand but also a slow ability to restore production because of supply chain component shortages. Some 25 ATRs were delivered in 2022 and an increase to around 40+ is projected for 2023. In the case of De Havilland the final aircraft from the Downsview facility were delivered in 2022 and a decision on any re-launch of production at a new facility in Calgary is not expected imminently and may still be some time away.

None of the new technology aircraft are expected to be delivered before 2026 at the earliest.

Figure 3.6: ATR72-500/600 & Dash 8-400 Delivery Profile (1994-2022)



Source: Ascend by Cirium & TrueNoord Insight

3.4 Firm Order Backlog

Current Generation Aircraft

The firm order book for the ATR turboprop family stood at 173 units at the close of 2022 as shown in Figure 3.7. This comprises 139 ATR72-600s and 34 ATR42-600s. Compared to the data used in 2020's Large Turboprop Report when the backlog for ATR72s was 162 units this represents a reduction. Although, production has also slowed markedly since 2020 and the Dash 8-400 is now out of production, this does not necessarily signal a medium to long-term reduction in demand for turboprops. The hiatus of the COVID pandemic and its after-effects combined with more recent short-term uncertainty means that it would be premature to draw long-term conclusions from data relating to the last three years. In addition, although absolute order volumes are still reduced, the diversity of carriers in the order backlog has grown so that more customers appear with smaller volume backlogs. Any such growth is regarded as a positive future market signal. In addition, some of the big order backlogs including Federal Express and IndiGo have reduced as the aircraft continue to be delivered and enter service.

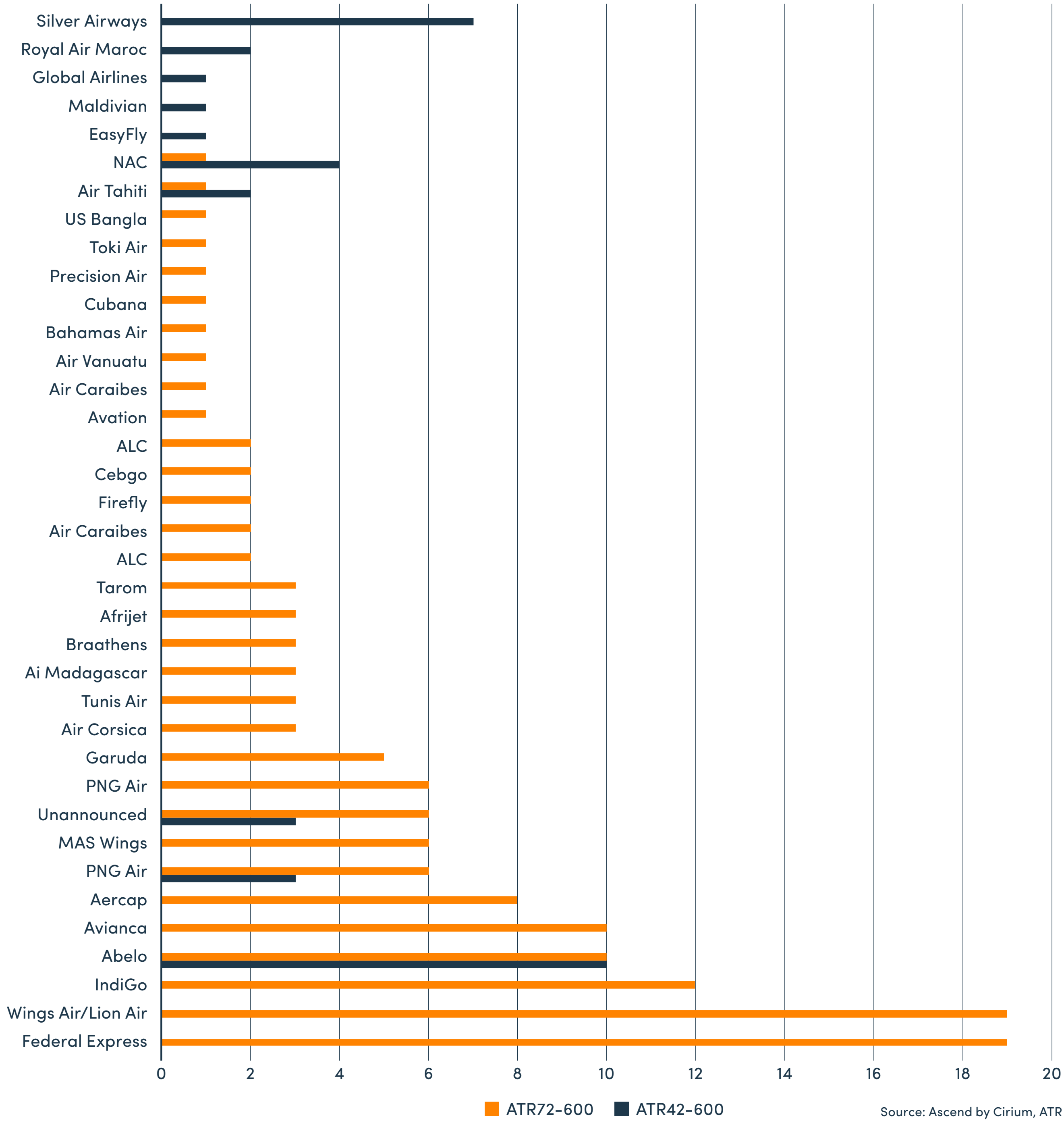
Philippine Airlines

TrueNoord Fleet
2 Dash 8-400

As with any commercial aircraft programme, the role of forward order lessors is important. However, the value of such forward orders is not the same as in the larger single-aisle market for several reasons. First, the absolute market size and the number of operators in the turboprop market is much smaller than the narrowbody segment so that placement opportunities for aircraft ordered without a specific lessee in place are more limited. Secondly, access to delivery slots directly from the manufacturer is easier in the turboprop market as delivery lead times are shorter. Typically, such order to delivery lead times are no longer than two years, unless any such requirement is above a single digit volume. Consequently, the prevalence of lessor forward orders is less than for the larger aircraft market and indeed turboprop manufacturers are less motivated to sell delivery positions to lessors as the smaller scale of the market means that the risk of the OEM finding itself in competition with lessors to place aircraft with both new and existing airlines is greater.

Nevertheless, lessor forward orders do have a role in the market. Historically NAC as the largest turboprop lessor before the pandemic had a substantial forward order book, which had already diminished to some 20 ATR72s in 2019 and now has five positions remaining. AerCap has inherited the remaining slots from GECAS and Abelo has increased its commitment to 20 equally divided between ATR42-600 and ATR72-600 aircraft.

Figure 3.7: Outstanding ATR Turboprop Orders (Dec 2022)



Source: Ascend by Cirium, ATR

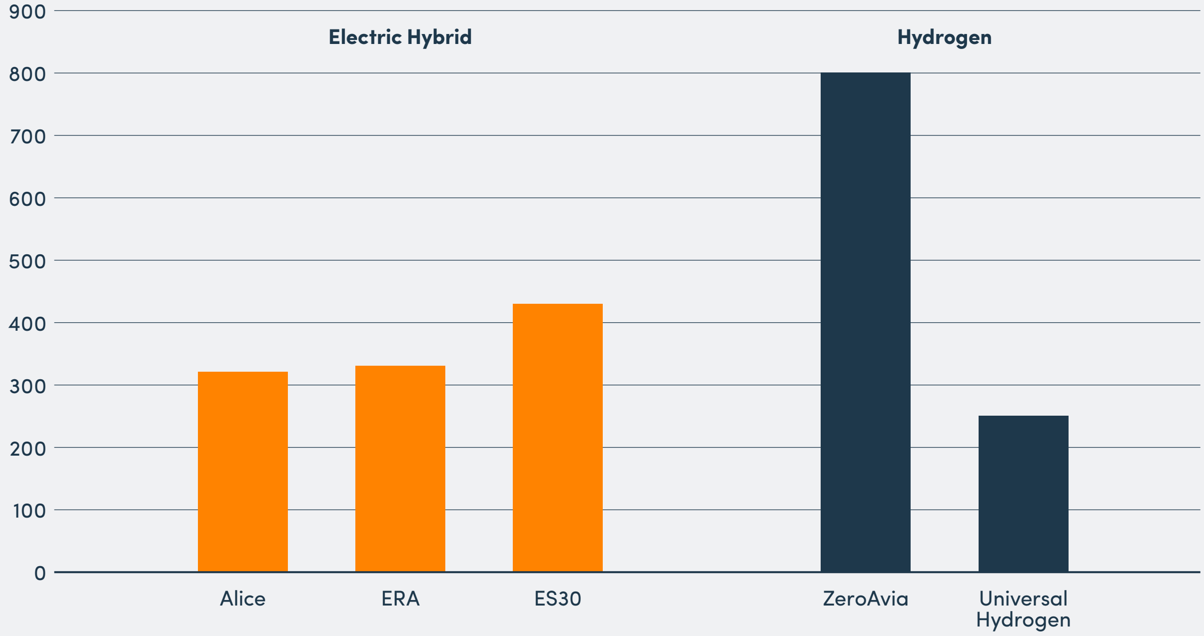
Future Generation Aircraft

Of the subject aircraft considered in this report, all of the new technology types have garnered a level of interest that can at this stage be measured by the signature of Letters Of Intent (LOI) shown in Figure 3.8. Therefore, these commitments cannot be compared to the firm orders shown above for existing generation turboprops, which do not show options or LOIs. Although some state that a portion of the LOIs are firm, all the new technology OEMs wish to convert the LOIs to firm orders, but it is not clear what milestones would need to be reached for customers to be sufficiently confident to place firm orders or when such conversions could take place.

As it stands there are approximately 1,000 commitments with varying degrees of firmness across each of the two hybrid electric and H2 powered pathways. All of the latter are to be retrofitted to existing airframes from Cessna Caravans up to ATR72 airframes although a portion of the ZeroAvia powertrain commitments are also envisaged on CRJ regional jets in North America.

With respect to the intended operators for these commitments, there is insufficient data to generate an accurate breakdown. However, the list does include major airlines ranging from Air New Zealand, DHL, Mesa, Afrijet to Connect Airlines and Air Canada.

Figure 3.8: Future Technology Commitments (Dec 2022)



Source: Eviation, Aura, Heart Aerospace, ZeroAvia, Universal Hydrogen, Ascend by Cirium

3.5 Future Turboprop Forecast

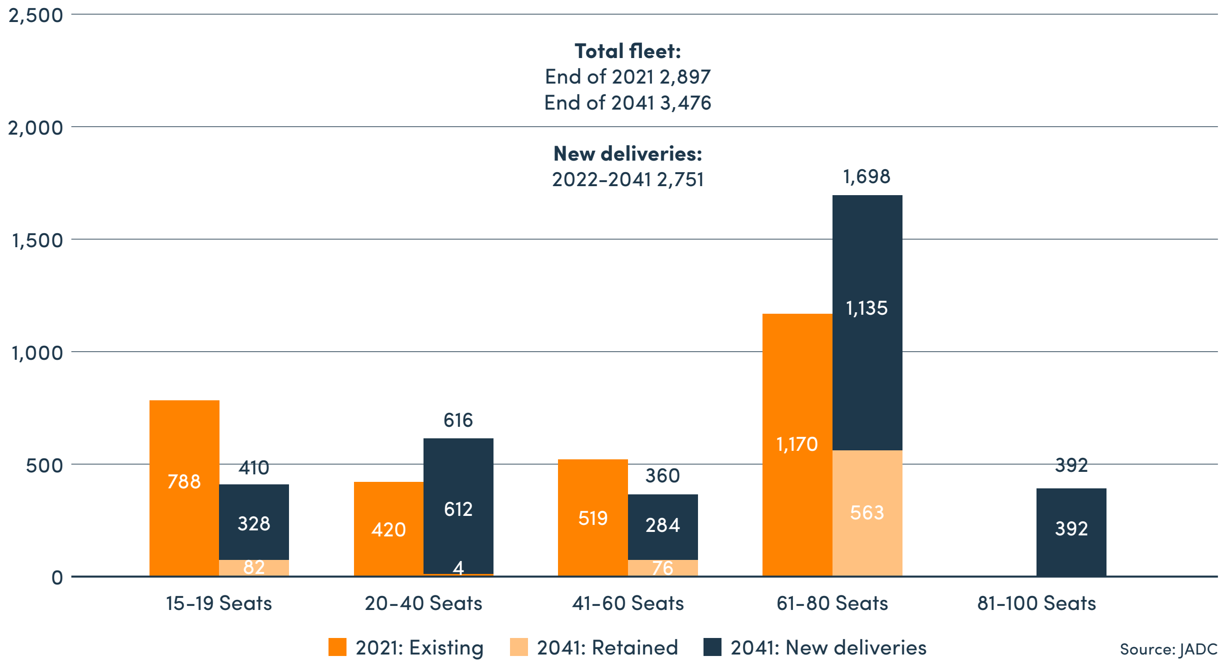
The provision of any forecast for the future demand and size of the turboprop market is outside the scope of this report so that the following brief guidance is intended as an overview of third-party projections only.

Current Generation Aircraft

Both ATR and Embraer provide forecasts for the turboprop sector. De Havilland has paused the Dash 8-400 and has also not published any recent market forecasts. Any future De Havilland forecast is a precursor to its decision on whether to re-start production of the Dash 8-400 in Alberta.

Japan Aircraft Development Corporation (JADC) provides a detailed forecast analysis which includes a section on turboprops as shown in Figure 3.9. Compared with the current fleet as measured by JADC of some 2,900 units of all sizes between 15 and 100 seats, 2,751 new deliveries are forecast. As the incumbent turboprop fleet is aging JADC projects that 79% of the new deliveries will be to replace the existing fleet and 21% will be for growth. However, it is not clear to what extent, if at all, any alternative propulsion aircraft are included in this view. As the JADC forecast projects a much higher growth projection for larger jet aircraft of nearly 50%, this would suggest that alternative propulsion aircraft are either not included or form only a minor part of the forecast.

Figure 3.9: JADC Turboprop Market Forecast to 2041



Source: JADC

By contrast, the ATR forecast projects global demand for 2,450 aircraft in the 50-70 seat category compared to some 1,420 in the JADC view. Embraer projects demand for some 2,300 turboprops but does not specify what seating capacities are included.

Future Generation Aircraft

As yet there are no forecasts predicting the number of new technology hybrid electric or hydrogen powered aircraft to be delivered for commercial service by a certain date. There are some forecasts that attempt to predict the monetary value of these sectors by 2030 and beyond. For example, the Monetary Research Community (MRC) projects the market for electric powered aircraft to reach US$26.4 billion by 2030 with a Compound Annual Growth Rate (CAGR) of some 14.5%. Another, Allied Market Research, projects the hydrogen aircraft market to be worth US$23.7 billion by 2030 with CAGR of 20.5%. Others project varying amounts.

Any addressable market for future technology aircraft will be driven by a combination of older and current generation aircraft that could be replaced and an amount of aircraft for growth. According to Ascend by Cirium, there are currently 4,422 commercial turboprop airliners in service and 1,241 in storage. Outside the aircraft within the scope of the less than 2,000 aircraft in this report, the majority of the remaining 2,500 are now ageing aircraft in excess of 30 years old. If these aircraft are not replaced then the services that they currently operate will either discontinue or would need to be operated by other, predominantly larger, aircraft types.

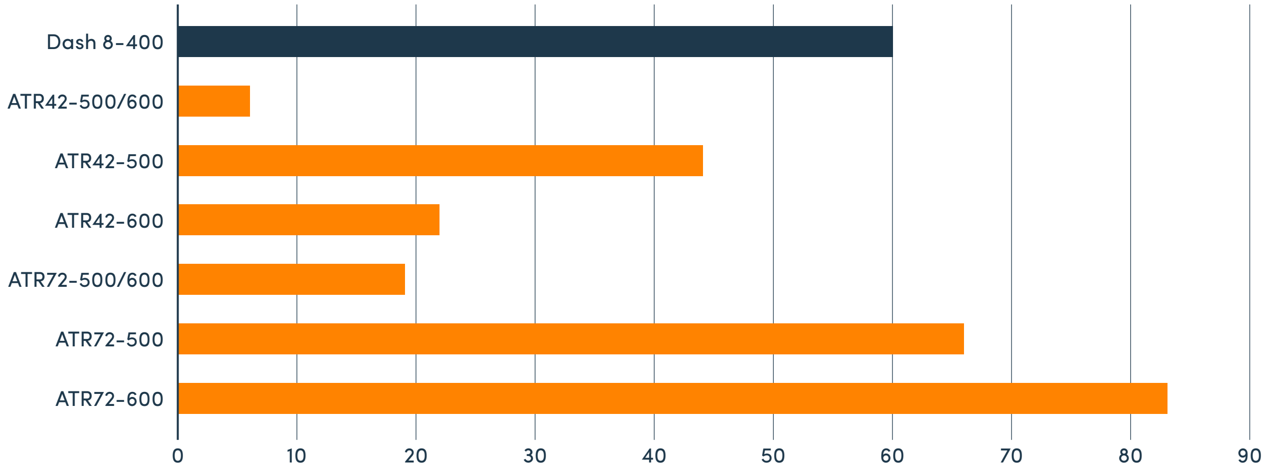
The majority of the above referenced ageing 2,500 aircraft in the 19-40 seat category could arguably be regarded as a conservative baseline replacement demand level for the current future technology aircraft described in section 2. This assumes that cleaner or emissions free propulsion delivers no growth in market demand. If the new technology delivers lower or emissions-free propulsion at a cost which is similar to or less than using conventional aircraft it is likely that there would also be significant growth in this smaller capacity segment.

3.6 Turboprop Operator Base

The absolute number of operators of any particular type is a vital determinant of its suitability as a leasing product. This is a prime driver of liquidity by showing the number of operators that could absorb additional incremental aircraft. On its own the number of operators is not a sufficient indicator of liquidity as a strong operator base can be materially weakened if there is an excess concentration of aircraft with a small number of operators. This can reduce liquidity and poses a risk if any of the largest carriers go bankrupt, or unexpectedly phase out the type thereby creating a large pool of available aircraft. This means that the level of concentration is an equally important measure.

The number of operators of the subject 50-90 seat current generation turboprops is shown in Figure 3.10.

Figure 3.10: Number of Turboprop Operators in Dec 2022



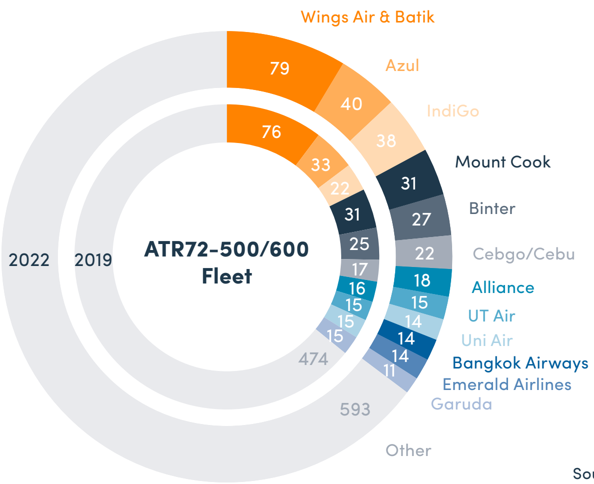
Source: Ascend by Cirium & ch-aviation

3.6.1 ATR 72 Operators

Currently the number of ATR72-500/600 operators is approaching 150 with 18 carriers that continue to fly a mixed fleet of both -500 and -600 variants. This is the largest operator base of any regional aircraft type and has grown further since December 2019. Since then an additional 15 airlines have newly adopted or transitioned to the ATR72-600. (There are currently 83 ATR72-600 operators compared to 68 in December 2019 and 56 in December 2017.) The number with a mixed fleet has reduced slightly from 20 in 2019 to 18 in 2022 but some have transitioned to an all ATR72-600 fleet and have therefore dropped out of this category and others have acquired the new model to either begin the replacement process or complement their -500s already in service.

The overall breadth of this operator base should be considered positive for future liquidity and residual values of the type. Within the total fleet there are only four carriers with fleets of more than 30 aircraft as shown in Figure 3.11. The largest operator is Lion Air's regional arm, Wings Air with 70 ATR72-500/600 and its sister airline in Malaysia (Batik formerly Malindo), with a further 9, represents 9% of the global fleet, followed by Azul with a fleet of 40 ATR72-600. The next largest operator and the fastest growing fleet is IndiGo. Air New Zealand subsidiary Mount Cook Airlines has a stable fleet of 31 units. As such, while there is some level of concentration at Wings and Malindo, there are no other carriers that account for concentration levels exceeding 4% of the installed active fleet base.

Figure 3.11: Largest ATR72 Operators (Dec 2019 & 2022)



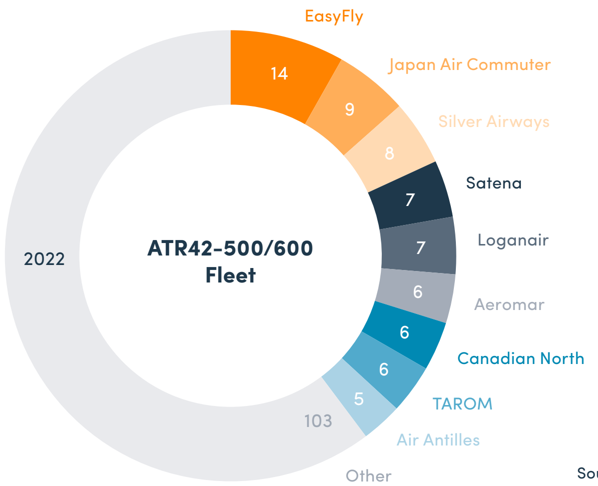
Source: Ascend by Cirium & ch-aviation

3.6.2 ATR42 Operators

There are currently 63 ATR42-500/600 operators including those in special mission roles for coast guard, surveillance and corporate applications such as transport to oil and gas installations or remote mines (Fig. 3.12).

Of these, 38 exclusively operate the ATR42-500, 19 only use the ATR42-600, and the remaining use a mixed fleet of both types. EasyFly in Columbia with 14 aircraft is the largest operator with 8% of the global fleet. No other operator accounts for more than 5% of the incumbent fleet and 60% of the total is with smaller carriers outside the ten largest. This means that although the ATR42 is more concentrated with the largest operators than its sibling, the operators' base can still be considered reasonably broad.

Figure 3.12: Largest ATR42-500/500 Operators (2022)



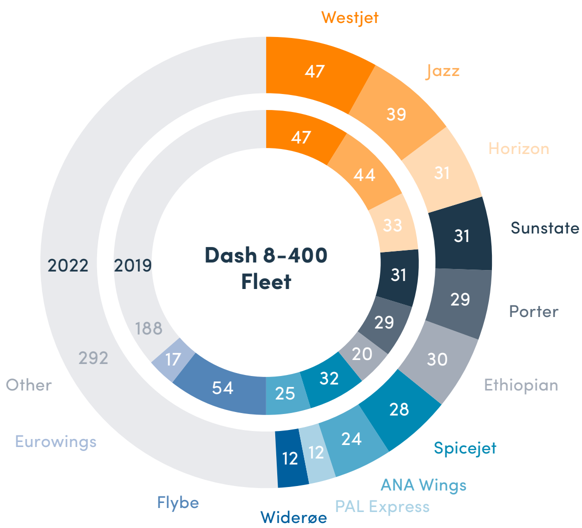
Source: Ascend by Cirium & ch-aviation

3.6.3 Dash 8-400 Operators

Currently the number of Dash 8 operators comprises of 60 carriers as shown in Figure 3.10. Despite the bankruptcy of Flybe and the exit of the type from other fleets including Eurowings, this number of carriers has remained stable since 2019 (58). By the time the planned disposal of the Air Baltic and LOT fleets are complete this number will remain the same as in 2019. This is still a reasonably substantial base despite the negative market sentiment surrounding the type.

While there is a substantial Dash 8 operator base, there are also a number of large carriers within the customer base. WestJet Encore is the largest operator with 47 aircraft, which accounts for 8% of the worldwide fleet. When Jazz, Horizon, and Sunstate (operated for Qantas) are added, 150 aircraft of the total fleet of around 575 aircraft are concentrated in 4 carriers. As shown in Figure 3.13, this does represent a certain level of concentration among key operators although the bankruptcy of Flybe in particular has reduced this concentration level compared to 2019.

Figure 3.13: Largest Dash 8-400 Operators (Dec 2019 & 2022)



Source: Ascend by Cirium & ch-aviation

However, while the Dash 8 fleet does exhibit a level of concentration, the fleets of similar sized regional jets are more concentrated within a small number of airlines. For example, the CRJ900 fleet is heavily dominated by Endeavour (for Delta), PSA and Mesa (both for American Airlines). Any such concentration can pose a risk to residual values but can also underpin values as is the case with the E175 fleet, which is heavily concentrated at Republic and SkyWest and likely to remain in service at both in the long-term.

3.6.4 Relative Concentration

For the ATR72 such levels of concentration are no different to the large fleets of narrow bodies operated by some of the large US legacy airlines and LCCs such as Southwest or Ryanair.

Moreover, the fleets of similar sized regional jets, the CRJ900 and E175 are substantially more concentrated within a small number of airlines with the former heavily dominated by Endeavour (for Delta), PSA and Mesa (both for American Airlines). Similarly, the E175 fleet is heavily concentrated at Republic and SkyWest. Each of the CRJ900 and E175 have narrower operator bases of some 20 carriers each.

Furthermore, the concentration levels of the ATR72 compare favourably with those of the Dash 8-400 where 26% of the total fleet is with only four airlines. While the ATR is less concentrated, the Dash 8-400 still has a broad operator base relative to similar capacity regional jets.

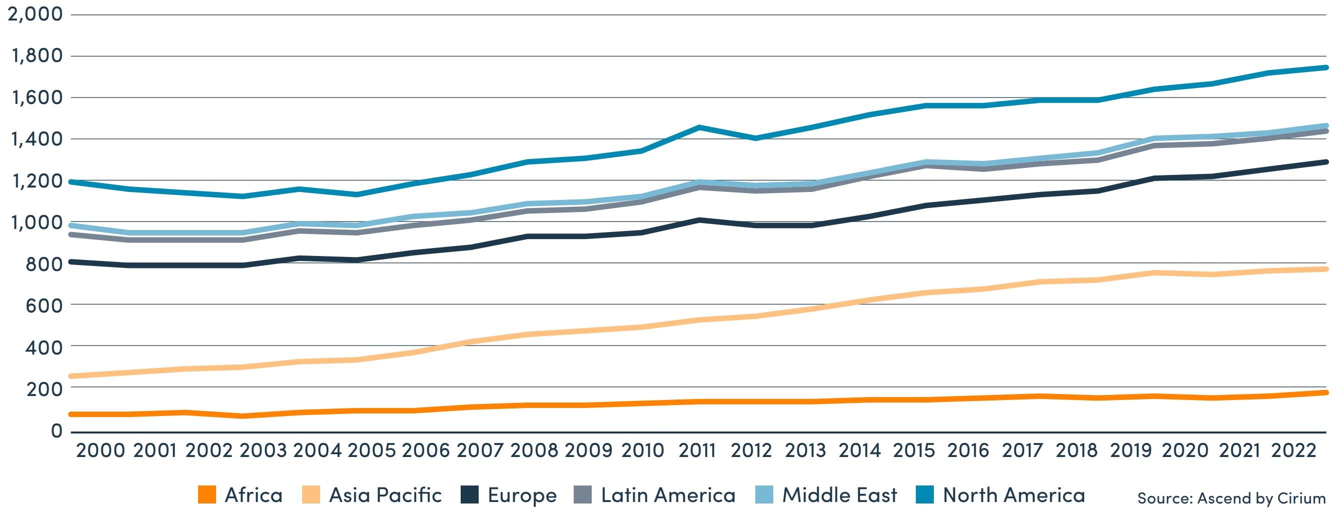
3.7 Geographical Dispersion

3.7.1 Historical Perspective

From a lessor perspective, a wide geographical distribution is desirable since this assists market liquidity and placement opportunities in the secondary market. Often if a type falls out of favour in one region, such as North America for turboprops in the early part of the century, (as can be seen in Figure 3.14), this can affect several operators in the same region so that an ability to place used fleets in other regions is important.

While Figure 3.14 shows large turboprops upwards of 50 seats to indicate the regional evolution since 2000 when the current 70+ seaters were less prevalent, there has always been geographical dispersion. However, while Europe accounted for almost half the entire market in 2000, Asia Pacific has become the largest market since 2012. The European market share has declined and all others have grown moderately or remained stable. During the period the US turboprop market also declined but was compensated by substantial growth in Canada. Today's large turboprop market can be described as geographically well diversified.

Figure 3.14: Global Turboprop Fleet Trend By Region (2000-2022)



Source: Ascend by Cirium

3.7.2 ATR42/72 & Dash 8-400 Geographical Dispersion

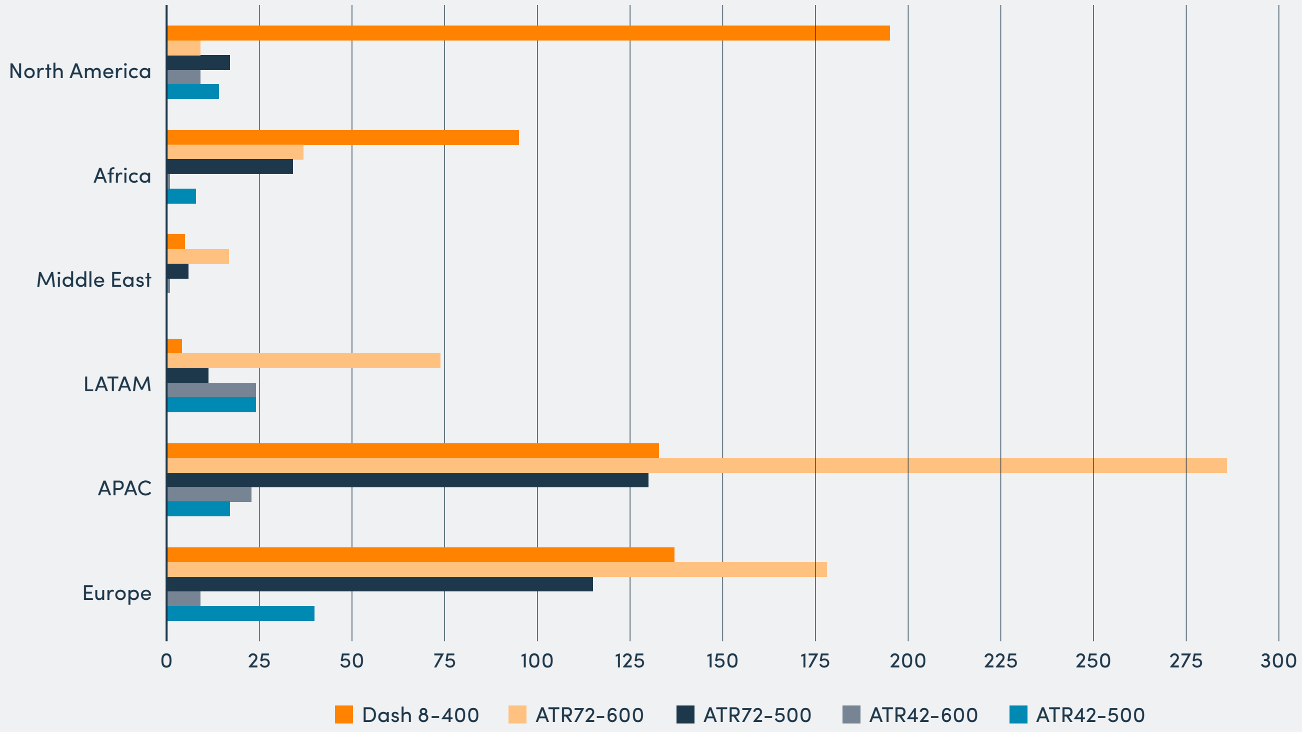
The world's fleet of ATR aircraft remains widely dispersed with the Asia Pacific region and Europe accounting for the largest portion of the entire fleet (Figure 3.15). This makes the APAC region the world's largest current generation turboprop market with almost 500 units. The ATR is the dominant turboprop in all markets except North America where the Dash 8-400 is market leader. In the smaller African market, the Dash 8 is also slightly ahead.

At present, the geography of the newer ATR72-600 fleet is more concentrated in the APAC region. This region now accounts for 47% of in ATR72-600s, while its second largest market in Europe accounts for 29%. North America is almost absent from current generation ATRs with only 18 of both -600 variants. However, Federal Express has placed a large order for freighters of which ten were delivered by the year end 2022.

By contrast the Dash 8-400 has performed strongly in North America primarily in its Canadian home market. While according to Figure 3.15 the type appears to still have a reasonable presence in Europe, much of this fleet is either stored by operators looking to dispose of their fleets, or by lessors that have returned aircraft, or repossessions following bankruptcies. The only growth market is Africa where its performance characteristics make the Dash 8 more suitable to that market.

With respect to the smaller ATR42-500/600 fleet, Europe, Latin America and Asia account for some 40-50 aircraft in each (82% of the global fleet) with the smaller remainder divided between North America and Africa.

Figure 3.15: Geographical Distribution of the ATR42/72 & Dash 8-400 Fleet (Dec 2022)



Source: Ascend by Cirium

3.8 Operator Segmentation

The ATR72 operator base comprises some strongly regarded carriers including Air New Zealand subsidiary Mount Cook, IndiGo and Binter Canarias, but there is a larger proportion of less well known independent regional airlines in the fleet or large carriers in developing countries. Some of these are financially less strong and operate in less stable jurisdictions.

By contrast, despite the loss of well-known names to the programme, particularly in Europe, the Dash 8 operator base still comprises an extensive list of better known airlines as many are either owned by major national carriers in developed jurisdictions, or operate on their behalf. For example, this includes strong home market names like Jazz which flies for Air Canada or WestJet, Sunstate which operates as Qantas Link in Australia, and ANA in Japan. Many of these are considered to be strong credits.

Part of the explanation for this divergence in their respective types of operator base is that the ATR72 is a lower cost regional aircraft optimised for short regional flights while the Dash 8 offers benefits as a feeder aircraft to larger carriers. For example, the Dash 8 is faster, if needed, thereby offering speeds closer to those of jets and equally importantly in some markets, passengers board the Dash 8 from the front (rear boarding in an ATR), which means airport air bridges can be attached. The latter is important in North America.

An additional contributing factor is a long-term strategy by ATR with respect to the secondary market, nurturing small operators deploying used aircraft as they may in future order new aircraft.

4 Large Turboprop Aircraft Owned by Lessors

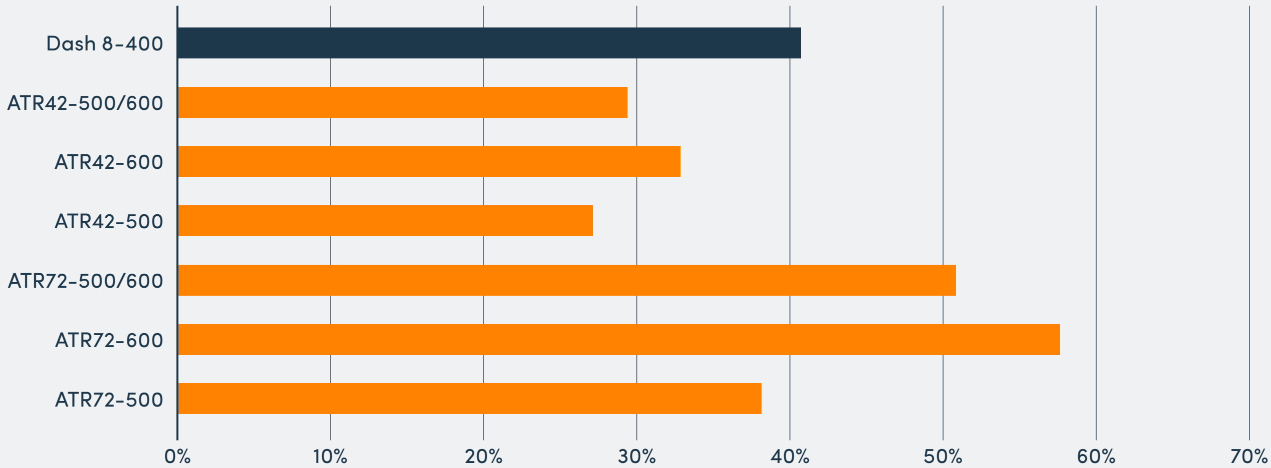
4.1 Comparative Lessor Penetration

The number of aircraft as a proportion of the total fleet is a strong indicator of the maturity of any type among the leasing community. A strong level of lessor penetration suggests that the aircraft is perceived as a strong asset class with good liquidity characteristics and high value retention. It is therefore not surprising to see the most popular narrow body aircraft with a penetration approaching 50% of all aircraft as shown in Figure 4.1.

Lessor penetration of the active ATR72 fleet at levels exceeding 50% is close to those of narrow bodies and suggests the type is more mature from a leasing perspective than any other regional aircraft type. The proportion of leased ATR72-600s is even greater at around 57% and lower for the ATR72-500 (38%). By comparison the proportion of leased Dash-8-400s stands at 31%, which is more similar to some of the regional jets. As less widespread types with relatively small fleets, the lessor penetration level for both variants of the ATR42 is also around the 30% level.

However, the number of active lessors in the large turboprop market is a fraction of the single aisle types (see Figure 4.2) and less than for some regional jets. Although the scale of the large turboprop leasing market is much smaller than larger aircraft, the smaller number of active lessors with scale is a positive factor that underpins their business models since this reduces the number of lessors that compete to fund aircraft for those operators seeking this type of finance.

Figure 4.1: Operating Lease Penetration Comparison by Aircraft Type (Dec 2022)

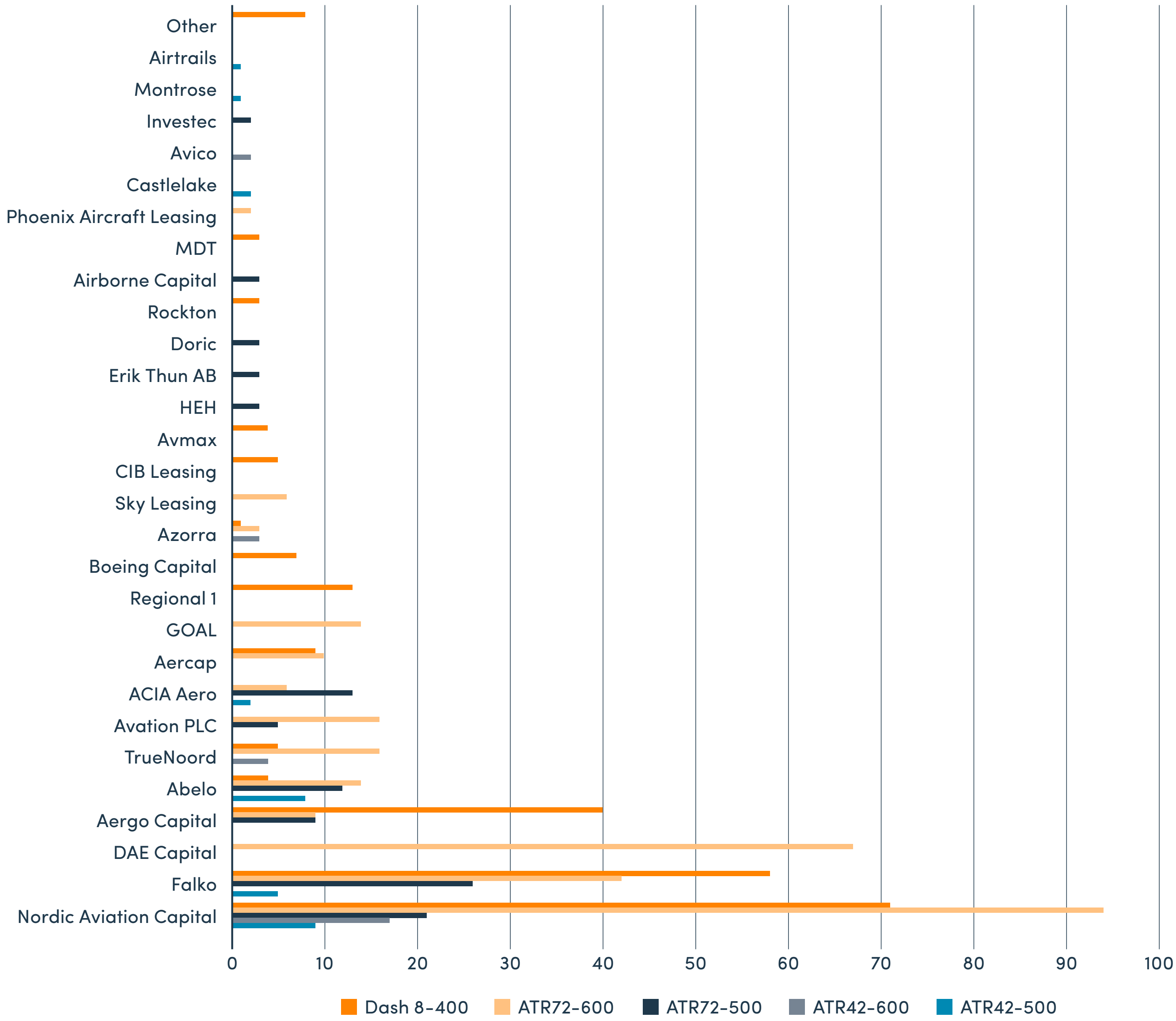


Source: Ascend by Cirium

4.2 Turboprop Leased Fleet Review

A breakdown of the main lessors of ATR72s is shown in Figure 4.2. This shows that despite some recent contraction, NAC remains the largest ATR lessor with 94 ATR72-600s and a further 21 ATR72-500s. (NAC is also the dominant Q400 lessor with 71 of the type). While DAE is the second largest lessor of ATR72-600s approaching a fleet of 70 aircraft, it has no other turboprops so that Falko, after its merger with Chorus, is now the second largest turboprop lessor with Aergo, Abelo and TrueNoord in fourth, fifth and sixth positions respectively. Beyond this and with only Avation and ACIA Aero owning more than 20 turboprops, the remaining lessors comprise those with small portfolios.

Figure 4.2: Large Turboprop Lessors Who's Who (Dec 2022)



Source: Ascend by Cirium & IBA

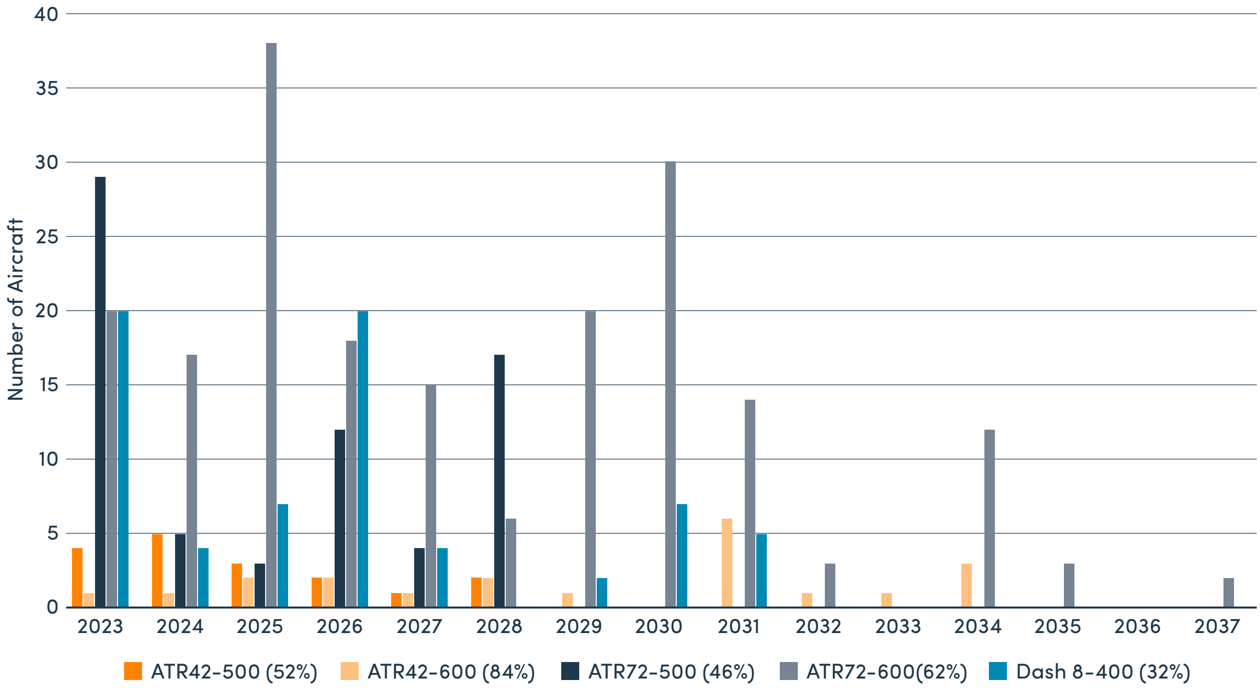
A significant driver of the ability to place an aircraft at good rentals at any particular point is the competitive position at that time. From a lessor's perspective, the case for leasing large turboprops improves if its lease returns are staggered over time and are scheduled to avoid periods when large numbers of similar aircraft also become available on the market, as this would minimise competition with other available aircraft.

Of the 337 leased ATR72-600s and 120 leased ATR72-500s aircraft recorded, the return dates are known for 209 -600s and 55 -500s (see Fig 4.3). This represents a more extensive set of data points compared to the previous report in 2020 but is still far from complete. For the ATR72-500, 8 are due to be returned from Wings Air this year and 5 from Nordic Regional. Based on the available lease return data, 2025 is the only year during which some 10% of leased ATR72-600s may become off-lease from Azul (6), Alliance Air (6) and Citilink Indonesia (6). Some of these leases may be extended, but 2025 could still be a year when an above average number of leased aircraft need to be placed.

With respect to the smaller ATR42 fleet, the -500 is an ageing aircraft type so that scheduled lease returns for most of the leased fleet over the next three years is to be expected. For example, Air Antilles has a number of leases due to expire over the coming years. By contrast the newer -600 variant has a much more evenly spread return profile and is the type where most lease end dates have been reported and are published.

For the Dash 8-400 only 32% of lease return dates are publicly available. Of those which are known, some two-thirds are due to be returned by 2026. The 20 due to be returned in this period includes most aircraft remaining in Europe, as well as significant numbers of Jazz and Ethiopian aircraft.

Figure 4.3: Known ATR42-500, ATR42-600, ATR72-500, ATR72-600 and DHC-8-400 Lease Returns (Dec 2022)



Source: Ascend by Cirium & IBA

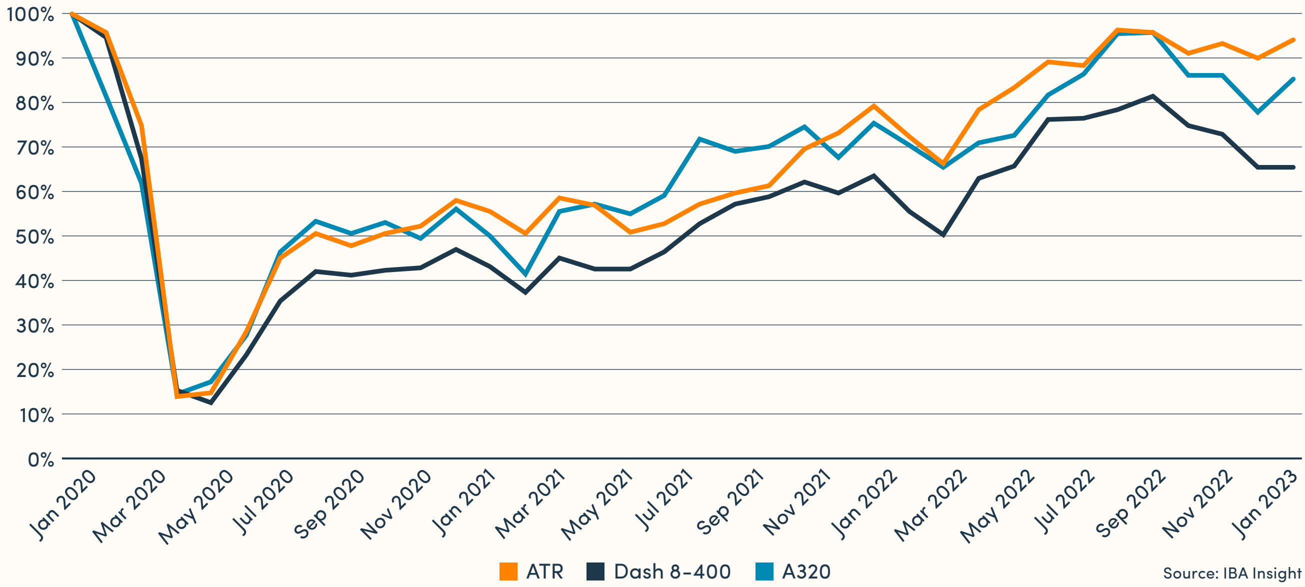
5 Market Availability and Demand

5.1 Demand and Supply Drivers

From a historical perspective, as older generation ATR42, ATR72 and early Dash 8-400s continue to age, it is normal for top tier carriers to seek to roll over their fleets into newer generation equipment. This would have the effect of increasing the supply of used aircraft unless a similar number of aircraft were retired at the same time. This could be measured by either the number of aircraft offered for sale or lease, or the number of aircraft in storage in the short-term at any point in time. The latter has been used as an indicator for availability over many years as there is no complete way of measuring aircraft offered to the market.

However, the COVID-19 pandemic caused a massive drop in flights for the majority of all aircraft including turboprops as shown in Figure 5.1 for ATRs and Dash 8-400 (A320s are also shown as a wider industry comparison). On the demand side during the recovery period, the ATRs have returned to service as quickly and at certain times faster than the A320, but the Dash 8 has underperformed and remained at only two-thirds of pre-COVID levels at the end of 2022. The latter was driven by a combination of the bankruptcy of its largest operator Flybe and the decision by several other airlines not to reintroduce the type.

Figure 5.1: ATR42/72-500/600, Dash 8-400 and A320 Flight Cycle Evolution (Jan 2020-Dec 2022)



Source: IBA Insight

The initial plunge in demand led to a proportionally corresponding jump in stored turboprops is shown in Figure 5.2. This spike in 2020 and more gradual recovery thereafter renders it difficult to use aircraft in storage as a proxy for availability until the demand environment has normalised.

5.2 Large Turboprop Availability – Aircraft in Storage

There is no complete inventory of aircraft available for sale or lease at any point in time, which is why stored aircraft data has often been used as a proxy. Apart from the above pandemic induced issues with this measure, the weakness of this proxy at any time is that it includes aircraft that are in transition between lessees, or sellers and buyers, as well as those that may be temporarily stored or parked for a variety of reasons. (The pandemic and subsequent recovery also introduced much longer lead times for maintenance capacity and parts so that this has caused many aircraft to remain unnecessarily classified as stored.) The trends for future lease returns and likely disposals in the leased fleet analysis above and fleet transition data are also indicative of the future market. In addition, the analysis of the real availability levels discussed below, which removes some aircraft that are known to be committed to other operators or in maintenance, is also important.

In the short-term ongoing recovery period, the number of aircraft in storage is trending downwards towards 20% (Figure 5.2) of the operating fleet (52 aircraft) for all ATR42s and 236 for all ATR72 variants including older -200 models. This compares with 30% (157 aircraft) for the Dash 8. While any large inventory in the number of aircraft stored is normally considered discouraging, the pandemic induced situation means that further analysis and segmentation is required as described below.

The storage commentary below relates to current in-production ATR-42/72 models and the Dash 8-400.

ATR42-600 Stored Aircraft

In December 2022 there were 4 ATR42-600 in storage, which represents less than 6.5% of the total fleet. This level of stored aircraft is much closer to the historical proportion of stored aircraft before the pandemic and can be seen as broadly positive. In the meantime, most of these are now believed to have returned to service or transitioned. This compares to 32 stored ATR42-500s.

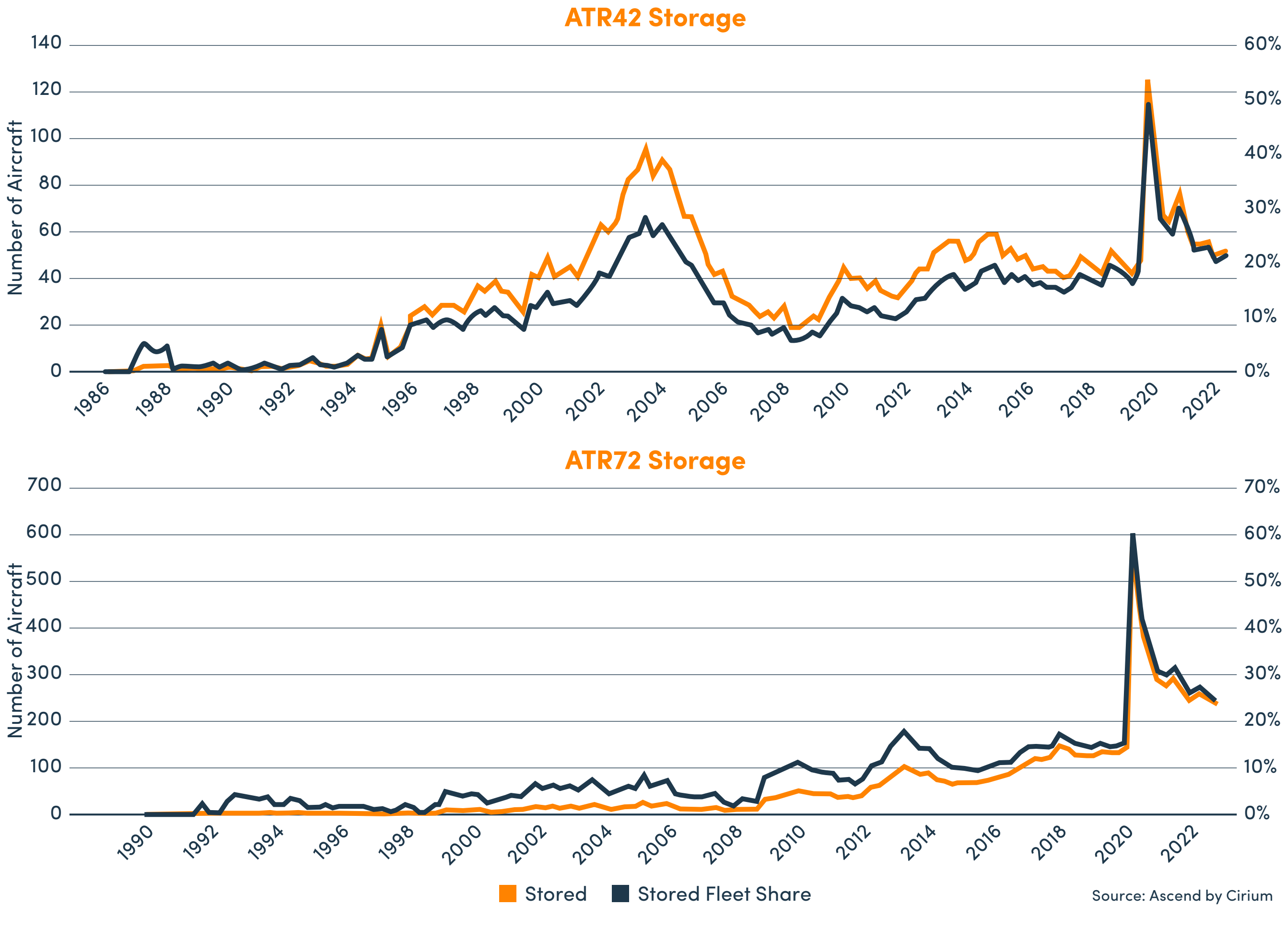
ATR72-600 Stored Aircraft

Of the stored aircraft, 110 are ATR72-600s, which represents a large increase compared to 2019. However, many of these aircraft have been in storage since the early part of the pandemic and many are either in poor condition or require significant investment to make them airworthy. Some, including six that last operated at NAM Air in Indonesia, have been stored since before the pandemic and would now require uneconomic amounts of maintenance expenditure. Others including 10 at Iran Air and five at Windrose are also stored and cannot be placed elsewhere, and a further 10 former Avianca aircraft have been sold to an investor for onward placement. Several other major operators in Asia including Wings Air/Batik Air, Uni Air, and Bangkok Airways have some 15 aircraft between them still temporarily stored and this more than likely reflects delayed maintenance inputs. This means that the actual amount of available airworthy aircraft is a fraction of the total stored number. Only a small number are publicly advertised for sale and a substantial number of those owned by lessors are understood to be committed for delivery during the first quarter of 2023.

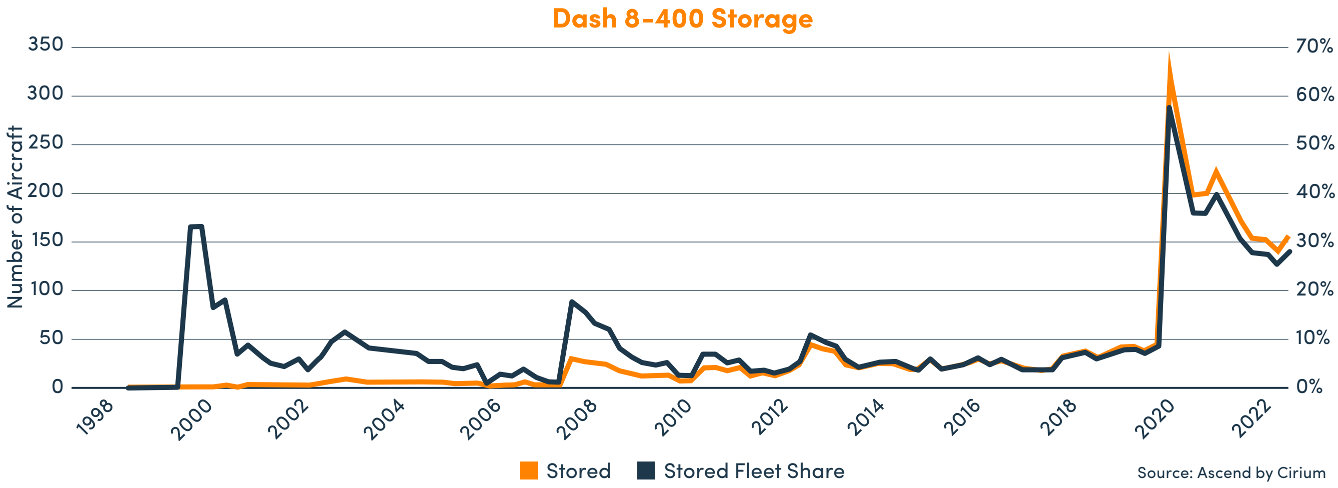
Dash 8-400 Stored Aircraft

By the end of 2022 the recorded number of stored aircraft had increased to 141 from 37. Of these 58 are the more desirable current (post 2009) Next Generation (NG) models. Ten of these were classified as stored in the SpiceJet fleet as at Dec 2022 and most are likely to return to service shortly. A few more classed as stored are owned by Ethiopian and a single Widerøe example was also temporarily stored. Four NG models that were previously at each of Air Baltic, LOT and the former Flybe have been placed. However, despite their young age many of these have been parked for some time and will therefore require investment, which means that at current relatively depressed rental levels this may prove uneconomic. The majority of parked aircraft are older pre-2010 examples. Furthermore, some of the Dash 8-400NG aircraft that are classified as parked are not stored because of any lack of demand, but rather because their engines require shop visits. Engine MRO capacity and therefore availability of slots for PW150A engines is currently constrained.

Figure 5.2: Numbers of Large Turboprop Aircraft in Storage (Dec 2022)



Source: Ascend by Cirium



5.3 Placement of Used Aircraft

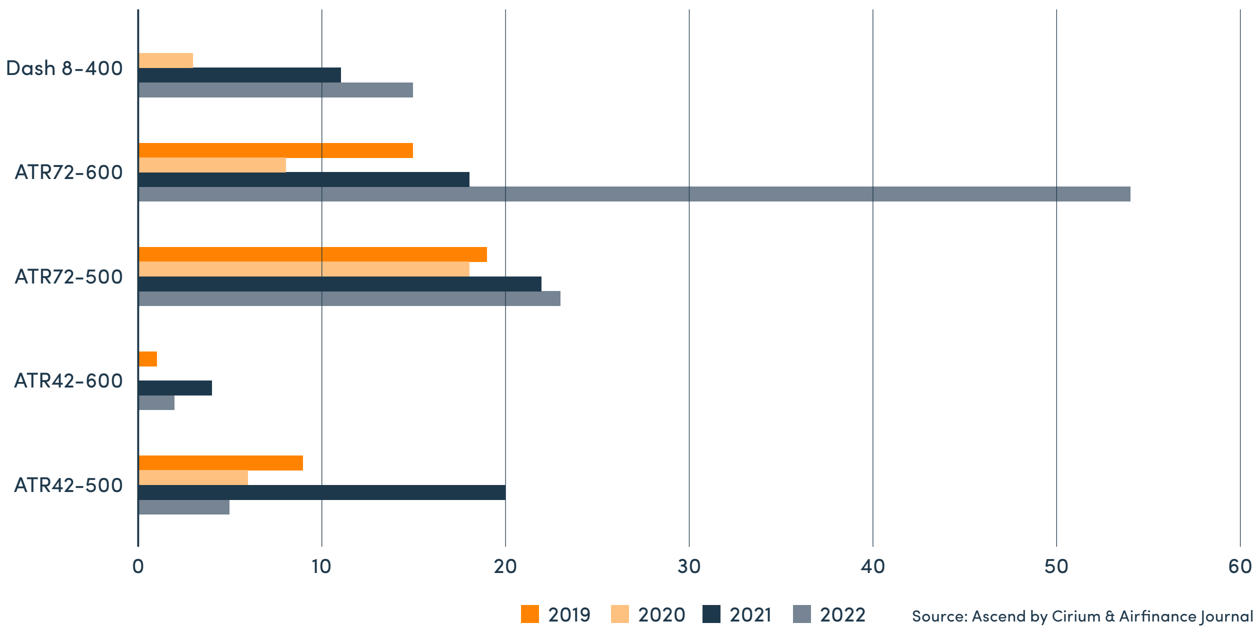
Since the beginning of 2019 and as shown in Figure 5.3, existing owners have demonstrated some success in developing new markets for used turboprops, with over 250 used aircraft transitions to new or existing operators completed since early 2019 either through aircraft sales or new leases. Of these all but 29 placements related to ATRs. This represents 5% of the Dash-8 fleet and 20% of all -500 and -600 ATR aircraft. This shows a reasonably encouraging level of market liquidity that is slightly greater than all other regional aircraft types. Furthermore, these placements were made with a variety of operators in all geographical regions with no dominance of any single or small number of carriers.

Of the 47 ATR42 placements, these have been diverse over the period with Loganair and Canadian North standing out as each has acquired six used -500 examples.

In the case of its larger sibling, 95 and 82 ATR72-600 and -500 respectively have transitioned between 2019 and 2022. The biggest new operator in the period has been Emerald Airlines with 14 used aircraft leased in 2021 and 2022. These ATR72-600s, which all operate for Aer Lingus Regional include four that were previously Stobart Air units. Olympic leased nine -600s in 2021 and 2022. Air Cairo, which took delivery of five ATR72-600s in 2021-22 has committed to an additional five in 2023 from NAC, and Caribbean Airlines a further three from the same lessor.

Of the Dash 8 transactions a number of former Flybe aircraft have been placed with Conair as part of a conversion programme for forest fire fighting applications for which the performance of the aircraft is well suited, and more are understood to follow during 2023 and beyond.

Figure 5.3: Turboprop Secondary Market Transitions (2019-2022)



5.4 Risk factors

While both existing lessors and other owners have had considerable success in placing used turboprops (especially ATR72-600s) with other carriers against the backdrop of COVID-19, significant risk factors, which may affect demand, remain. At a macro level these include:

- Any economic deterioration globally or within certain key regions such as Southeast Asia (ATR's biggest market) could have a substantial negative impact on the demand for used aircraft.
- If the strong post pandemic recovery of 2022 continues, the trend towards up-sizing capacity to larger aircraft could resume and slow the demand for sub-90 seat aircraft.
- Any technological step-change particularly with reference to propulsion systems could impact the attractiveness of used turboprops. While hybrid electric and hydrogen powered aircraft are likely to become a reality in future, there is a wide industry consensus that such technology will not become widely available for 70+ seat aircraft within the next decade. It is possible that this technology could threaten the up to 50 seat segment a few years earlier.

At a micro level, it only requires one or two major carriers with substantial fleets to decide to dispose of their fleets to have a substantial market impact. As the ATR fleet is less concentrated in the hands of a few large operators than the Dash 8 or other regional aircraft types, this risk is smaller for the type. However, any significant disposal programme could dump significant fleets on the market in a short period, which would increase supply and thereby lower values and lease rates.

TrueNoord Fleet
3 ATR 72-600

6 TrueNoord CMV and FV Assessment

6.1 General Trends

For all commercial aircraft types including turboprops, the COVID-19 pandemic initiated a period of volatility in both aircraft values and lease rates. In the relatively small turboprop market compared to larger aircraft types much of this was driven by sentiment rather than a sufficient pool of data points. This market sentiment led to dramatic reductions in both appraised market lease rates and values in the second half of 2020 when commercial flights were still below 50% of pre-pandemic levels and the recorded number of inactive parked aircraft was at its peak. From late 2020 when some aircraft were re-activated and throughout 2021, some turboprops were leased at substantially below pre-pandemic rentals, but almost no trades of used turboprops occurred from which market values could be derived as sellers were unwilling to accept significant book value losses. This means that market values at the time were more theory than reality.

From about the second quarter of 2022 turboprop lease rates and Current Market Values (CMV) started to recover. At that time, it had become clear that the inventory of parked aircraft fell into two categories: those that were airworthy and could be re-activated with relatively little maintenance expenditure and those that had either been poorly stored or where the passage of time meant that considerable investment would be needed to return them to service. In combination with reduced production of new aircraft by ATR, De Havilland's halt in production and a shortage of MRO capacity, this led to a shortage of airworthy turboprops from the second half of 2022. In turn, this lack of supply caused a recovery in both lease rates and CMVs, which has been reflected by appraisers increasing their values although these have not yet fully returned to early 2020 levels. This has ensured greater market liquidity as evidenced in Figure 5.3.

New Values

During the pandemic years, values of newly produced aircraft from both ATR and De Havilland destined directly for airlines remained less volatile than those of used examples. In this period De Havilland delivered the last Dash 8-400 before closing its Downsview final assembly line. According to the average CMVs of appraisers (Fig 6.1 (iii)) these last of line units may have been discounted and are likely to reflect pricing that was applicable to large orders placed by Ethiopian in particular.

With respect to new ATRs there had already been some softness in new values before the pandemic. This had primarily been driven by lessors adopting a strategy of securing forward positions similar to large aircraft lessors. Production rates were increased to deliver these aircraft, but as the turboprop market is much smaller than the narrow body market, this led to some over-production. A few lessors, including some that previously had no turboprop exposure, which had purchased ATRs to both diversify and reduce the average age of their fleets then began to discount lease rates significantly in order to place their inventory. The pandemic served to prolong this until ATR dramatically reduced production rates to 10 units in 2021. By 2022 all remaining white tail aircraft held either by ATR or by lessors had been placed so that new values stabilised and recovered later in the year. (Fig 6.1 (i) & (ii))

Since the start of a higher inflationary environment in March 2022, production costs have risen and the previous industry standard escalation rates have also dramatically increased. While escalation applies to all aircraft manufacturers in similar ways it remains premature to determine whether these higher costs can be passed on to customers in higher acquisition prices. It would appear that appraisers have to some degree accounted for this in their base values, but so far not in CMVs.

Used Values

Both in the years preceding the pandemic and during the period thereof, used values have taken a different path for the ATRs and Dash 8s.

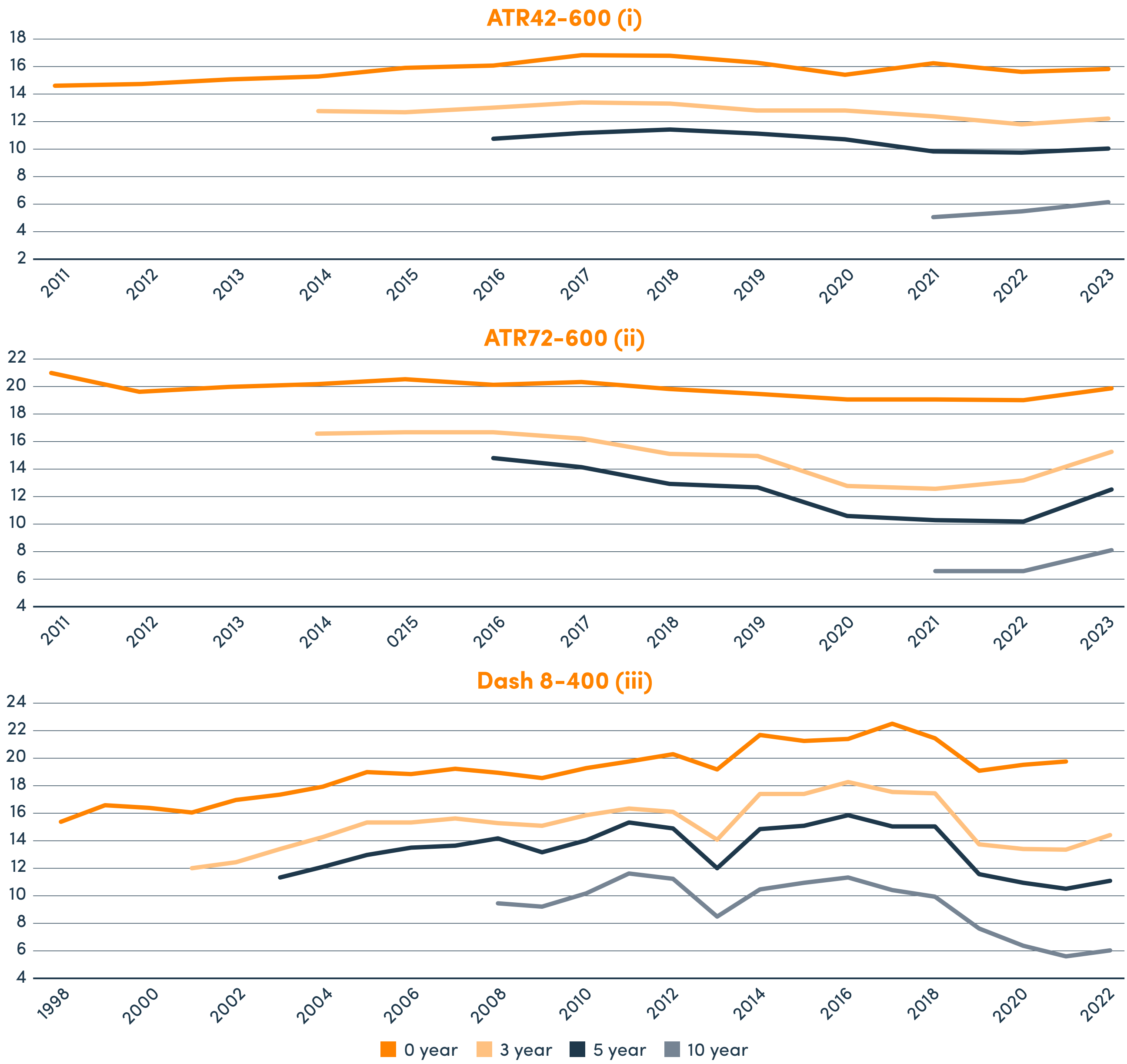
In the few years before the pandemic the demand for used ATRs was already soft so that appraised CMVs for 3-10 year old aircraft had become impaired (Fig. 6.1). This trend continued and accelerated with the onset of COVID-19 especially for the larger ATR72-600. From the middle of 2021 market demand and the lack of airworthy used ATR72-600s began to emerge so that by 2022 lease rates were recovering, which in turn led to appraisers increasing their CMVs. This trend seems set to continue in 2023 albeit possibly at a slower rate. It is also possible that if escalation leads to higher new aircraft prices that the cost of re-activating many of the remaining stored aircraft becomes more attractive than a year ago.

The smaller ATR42 market, which did not experience the same drop in appraised values is now also showing early recovery indicators. However, it should be noted that the market for used ATR42s is small so that appraisers rely on fewer data points than for other regional aircraft types.

In the later life ATR72-500 segment, there had been value stability in the pre-pandemic years as the cargo conversion market had absorbed a greater proportion of older aircraft, but during the pandemic years, CMVs slid similarly and in many cases faster than -600 variants. By late 2022 values and lease rates had stabilised but not yet shown many recovery signals.

Since fewer Dash 8-400s than ATRs have been sold both to end user airlines and lessors, lower production levels restricted supply in the pre-pandemic years and thus ensured that used values held relatively strongly. However, the start of the pandemic became the catalyst for not only the demise of the largest operator Flybe, but also a decision process that led several other carriers to decide that the Dash 8-400 would not return to service at many other European operators. This meant excess supply and markedly reduced lease rates and values (Fig 6.1 (iii)). Appraisers believe these have now stabilised and begun to recover albeit at a slower rate than the ATRs.

Figure 6.1: Turboprop CMVs Over Time (Jan 2023)



Source: TrueNoord analysis of average CMVs from Avitas, mba & Ascend by Cirium

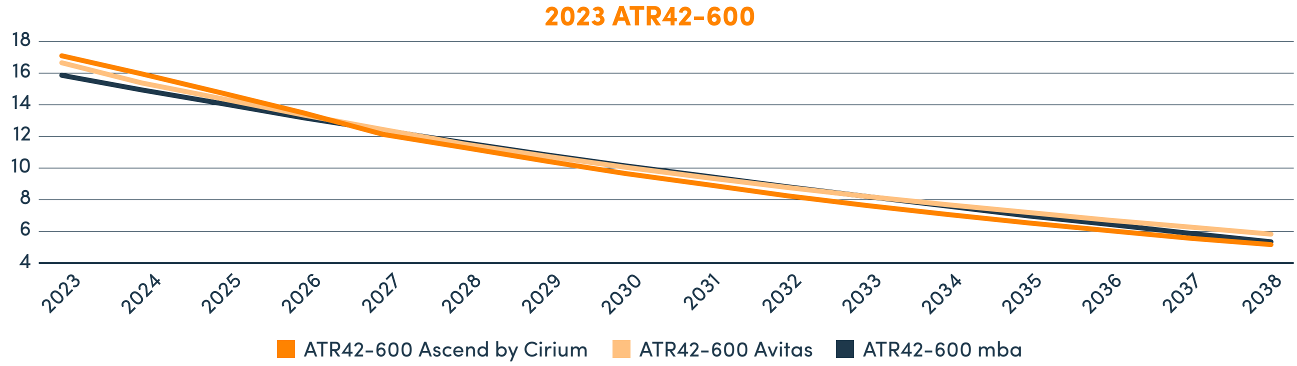
6.2 New Value Trends

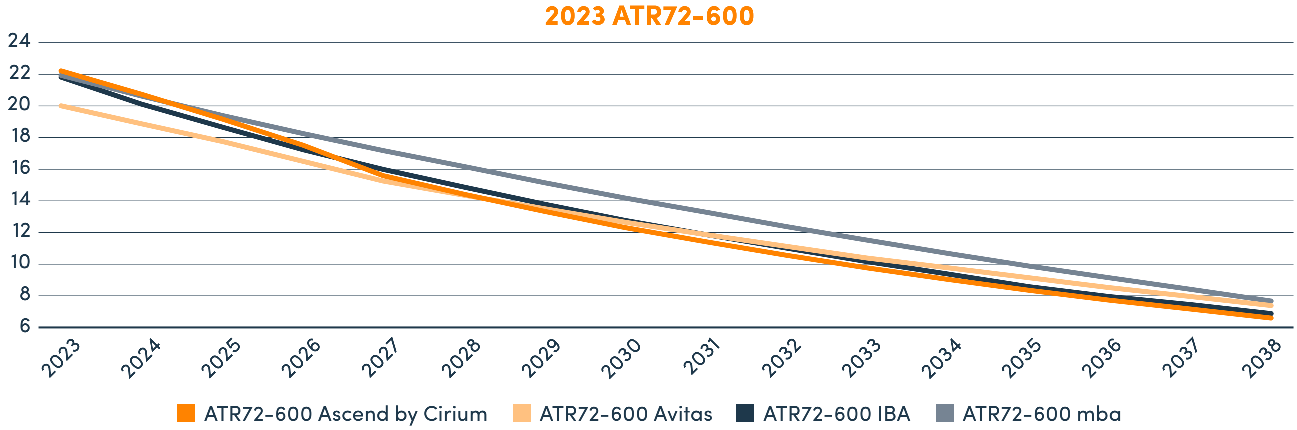
While new appraised base values for an ATR42-600 are in the region of US$17 million in early 2023 and US$22 million for ATR72-600s (with new CMVs some US$1million lower), there is some limited divergence for new values among the appraisal community as shown in Figure 6.2. The appraisers indicated show a range of US$15.9million to US$17.1million for a new ATR42-600 and diversity of views on the ATR72-600 of US$20 to 22.2million.

An average gap remains with respect to longer term future values for both ATR variants but this does gradually narrow in absolute terms over time. Ascend by Cirium, which starts at marginally the highest new value for both types, depreciates to its lowest value by 2030. By 2038 all appraisers have depreciated their future base values to a range that diverges by about US$1million. Similar to the previous Large Turboprop Report (2020), the average residual value after 10 years is close to 50% of the new value. This compares similarly to the best performing regional jets and favourably to the less popular types. Furthermore, the future value performance over time is comparable to mainstream single-aisle aircraft.

As the Dash 8-400 is currently out of production, no new values are shown. The previously mentioned reduced levels of production and the restricted supply of airworthy used examples have set a positive short-term outlook. Base values of the newest Dash 8-400s (2021 year of manufacture) are around US$19.5million with CMVs of around US$18million.

Figure 6.2: Appraised Base Value Profile New Turboprops in US$ millions (Jan 2023)





Source: Ascend by Cirium, Avitas, IBA & mba

6.3 Used Turboprop Values

While most appraisers and market participants concur that the long-term value retention prospects remain positive and should continue to follow a traditional depreciation profile, the short-term remains soft for both ATRs although much less so than even a year ago.

The smaller ATR42-600 market has seen very few transactions and therefore generated few data points over the last two years and is likely to remain a niche product in certain markets. In future this will include the new STOL variant. Once acquired, such niche market aircraft tend to stay with the same operators for much of their intended economic lives and are therefore less likely to be traded. Unless an operator of the type ceases operations it is unlikely that a fleet of aircraft big enough to affect CMVs or future values would occur. Potentially the greater risk to longer term future values of used ATR42-600s is their replacement by new technology aircraft. Given that this sub-50 seat aircraft category is likely to be replaced by new technology aircraft earlier than larger turboprops or existing jet aircraft, these aircraft could be more susceptible to obsolescence risk than others. This means that future values should be relatively stable in the medium-term but could have greater downside risk in the long-term.

For the ATR72-600 the medium to long-term future value prospects remain reasonably strong. Over the medium term no other aircraft in the 70 seat category can match its operating economics including fuel-burn and associated emissions and no new technology aircraft of its capacity is likely to be available over the coming years. The PW127XT engine provides further incremental improvement and can be fitted on existing used aircraft. The aircraft also lends itself well to hydrogen propulsion retrofit programmes as proposed by both Universal Hydrogen and ZeroAvia so that there is no reason to believe that the airframe will become obsolete over the next decade and beyond. Whether for the above reasons or others, the appraisal community has not materially altered its long-term future base value projections for the type.

The Dash 8-400 prospects and future value retention can be divided into older aircraft manufactured before 2010 and NG variants that entered service from early that year. A number of airlines in Canada, Africa and a small number elsewhere such as Widerøe in Norway that benefit from its performance characteristics (including range or greater speed) are likely to underpin their longer term values for NG versions particularly as the production run of more recent vintage units was restricted from 2010 onwards (Fig.3.6). For these, the average of appraiser depreciation profiles of 3-5 year old units over the long-term is similar to ATR72-600s with initial near term base values around US$2million higher and converging to a difference of around US$1million after ten years. For older pre-2010 examples excess supply is more likely to persist for some years to come. Thus values are more likely to trend towards soft levels. Appraiser future market values have to some degree accounted for this by ascribing values that are very similar to equivalent vintage ATR72s despite their initially higher values.

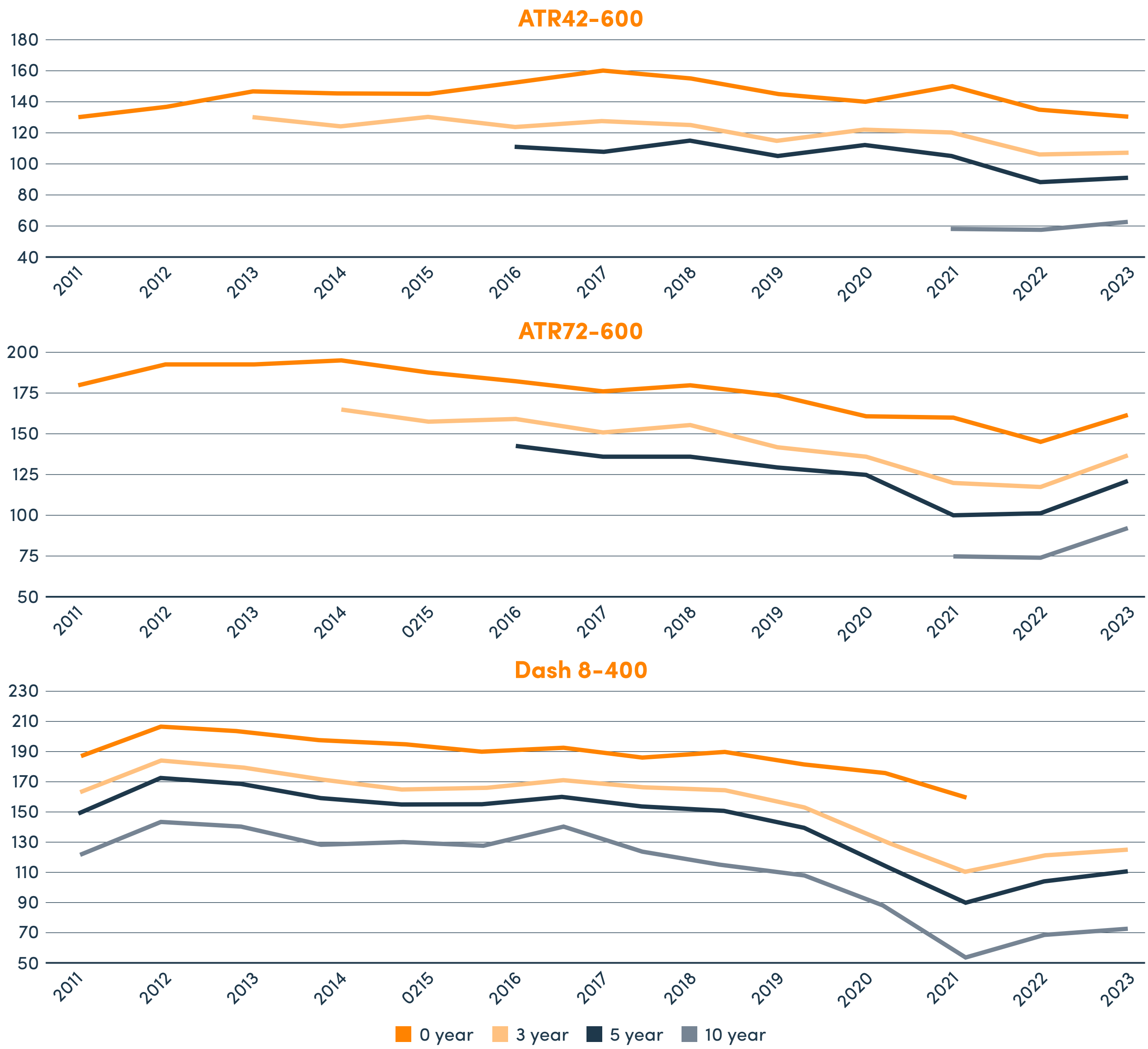
6.4 Lease Rate Trends in market

According to appraisers, new aircraft lease rates are at around US$130,000 per month for the ATR42-600 and approaching US$170,000 for the ATR72-600 as shown in Figure 6.3. In the case of the latter this still represents a reduced level compared to before the pandemic. As the Dash 8 production is paused no new lease rates are shown.

Figure 6.3 also tracks three, five and ten year old constant age Dash 8-400s and ATR42/72-600 lease rates since inception of this variant in 2011. For the ATR42-600, this shows that used aircraft lease rentals followed a similar pattern to new rates after 2016 with a more recent stabilisation. However, as there have been very few recent transitions (Fig. 5.3) the data points are limited to corroborate this trend. For the ATR72-600 lease rates for used aircraft trended similarly to new rates from 2014 and dropped faster during the early pandemic period until a stronger recovery occurred in 2022. This partly reflected an excess supply of new aircraft delivered since 2014 which naturally impacted used values. In practice some used ATR72-600s were placed at levels significantly below the appraised lease rates, but the more recent uplift is supported by recent data points.

The Dash 8 lease rates for used aircraft up to 10 years old peaked in 2011 and have declined by 12-15% since that time, and faster from the onset of COVID-19. Over the last year appraisers suggest that lease rates have recovered for vintages up to 10 years old. These are all NG variants, but as the number of sale transitions has been limited (Fig 5.3) there are few data points to be sure that this apparent trend is sustainable.

Figure 6.3: Turboprop Constant Age Lease Rates Over Time 2023



Source: TrueNoord analysis of average CMVs from Avitas, mba & Ascend by Cirium

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